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Studies on the System of Plant-ecology based on Field Investigations made in Northern East-Asia

By

MOTOO TAKAHASI

With 9 Figures, 9 Maps, and 53 Photographs in the Text

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Introduction

The writer, who was a member of the First Scientific Expedition to Manchoukuo under the able leadership of the late Dr. S. TOKUNAGA, published, in 1936, his report entitled "An Ecological Study of Vegetation in the Province of Jehol, Manchoukuo". Since then he has made numerous journeys, almost in the northern part of East-Asia, regardless of season excepting that of snow and frost, which lasts from October until the following April. His travels, which totaled more than forty thousand kilometers, embraced the coast of the Japan Sea, on the east, to the eastern part of the Gobi Desert, on the west; from the shores of Shantung (山東) Peninsula, on the south, to the banks of the Amur River, on the north; sometimes over high mountains, other times through virgin forests, or across wild deserts, and at times over vast steppes and prairies.

The present paper deals with the results of his investigations on vegetation made in the course of the foregoing travels, as also the results of his experimental studies in connection with ecological subjects in these regions, although they cannot in any sense be called conclusive. Owing, moreover, to the fact that the region explored was practically virgin territory, so far as ecological research is concerned, the writer was severely handicapped by the meagreness of literature on the subject.

The Regions under Consideration

The regions under consideration, namely, Northern East-Asia, lies between 35° N. L. and 58° N. L., and between 95° E. L. and 145° E. L., including Manchoukuo, the greater part of Inner and Outer Mongolias, the southern part of Eastern Siberia, and the whole of North China. This area, which involved about 7.500.000 sq. km, is almost equal to that of U. S. A. proper. The land forms met with in the regions visited are more complex than those of U. S. A., with its Rocky Mountains on the west, the Apalachian Chain on the east, and the Great Central Plain between the two, whereas the entire region visited by the writer, except in the North China Plain, the Mongolian Plateau, and the Central Manchurian Plain, mountains abound everywhere.

GEORGE B. CRESSEY,[1] in referring to the mountain chains in China, the northern part of which is included in the regions under consideration figuratively wrote —

> The mountains of China may be thought of diagrammatically as fingers reaching out from the Tibetan Plateau, which forms the palm of the left hand. The thumb, held uppermost and partially opened, may represent the Tien-Shan (天山), which enclose the Tarim (塔里木) Basin of Sinkiang (新疆) to the south. Across northern Tibet and continuing eastward into China are the ranges of the Nan-Shan (南山) and Kun-Lun (崑崙) Mountains, separated by the Tsaidem (柴達木) Swamp and the azure lake of Koko Nor (青海); these may be represented by the first and second fingers. In between the second and third fingers would be the Red Basin of Szechwan (四川). From here on the analogy does not hold so well. Perhaps it would be better to combine the third and fourth fingers to indicate the extensive but low and indefinite Nanling (南嶺), which extend across South China eastward and northeastward to the Pacific. Or the little finger might indicate the mountains south of the Si-Kiang (西江), which reach eastward to Canton (廣東) and are the shortest of the various mountain chains, just as those represented by the middle finger, the Tsingling (秦嶺), are the most important. Greatest of all the mountains of China is the eastward extension of the Kun-Lun, known in China collectively as the Tsingling-Shan, which reach eastward from Tibet nearly to the Pacific.

The Tsingling-Shan mountain range, which separates the North from the South, is the barrier, on which the moist winds from the Pacific lose much of their moisture and against which the cold and dusty northwestern winds of winter break their force. That is, this barrier separates the moist lands of Southern East-Asia, including Central and South China, and countries further south from the brown and dusty soils of Northern East-Asia.

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(1) CRESSEY, G. B.: China's geographic foundations. (1934) 38.

One of the most striking physiographic features of Northern East-Asia is the plateau of "loessial soil",(1) which has received no small attention on the part of ecologists, pedologists, and geologists. The rock materials underlying the loess consist largely of reddish clays, sandstones, and conglomerates, which are mostly of Tertiary age. Within this plateau, and extending above its general level in many places, are ridges of hard older rocks, such as sand-

Fig. 1. The wind-laid loess of northwestern China covers an area of 119,900 sq. miles. (G. B. CRESSEY)

stone, limestone, granite, shale, basalt, trachyte, and porphyry, the age of most of them being Jurassic or Cretaceous. Although the rocks that form the land are intimately related to its ecology, it being not so essential to the ecologist in his first general surveys of vegetations as that of the soils, details of the rock formations are excluded from the present paper. The loessial plateau grades off northward into the rocky and sandy Ordos wilderness which, doubtless, is one of the sources of the vast quantity of dust that now makes up the loess deposits. At the present time, the sand dunes of this waste region are gradually creeping southeastward with the prevailing northwest winds of the winter months, burying in places habitations and farm lands.

To the east of the Tsingling (秦嶺) range proper, the Funiu-Shan (伏牛山)

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(1) Detailed descriptions of this loessial soil will be found in the appropriate chapters.

range, south of the Hwang-Ho (黃河), in Honan (河南), has as its northern branch, the Taihang-Shan (大行山), which swings northward through eastern Shansi (山西), eventually to join in an indefinite manner the Yin-Shan (陰山) northward, near Peking (北京).

Another important mountain group in northern Shansi (山西) indirectly related to the system under consideration is the Wutai-Shan (五台山), which ties Tsingling (秦嶺) with the Nan-Shan (南山) system in the northwest.

The Nan-Shan, which marks the southern border of westernmost Kansu (甘肅), does not continue into the central part of the province beyond Lanchow (蘭州). Their eastern extent may be represented by the ranges that encircle the Ordos wilderness, outside of which is the Holan-Shan (賀蘭山), a narrow range reaching a maximum of nearly three kilometers. East of these mountains we find a band of rough, broken, and mountainous land, called the Yin-Shan (陰山), marking the border of the Mongolian Plateau. Topographically, but perhaps not structurally, these mountains turn northward along the Mongolian front to form the Great Khingan (大興安嶺山脈) range. The southern part of this range is the upturned and dissected edge of the Mongolian Plateau rather than a normal two-sided mountain. Farther north of these mountainous lands we meet with a rolling grassy plain, a kind of true steppe, with occassional hills and a few low mountain ridges. Still farther north, the hills and mountains almost disappear, giving way to a flat low steppe plain, and very dry grasslands.(1) On the border of the low steppe, the Gobi Desert—in the strict sense—which roughly marks the boundary between Inner and Outer Mongolias, begins and extends westward from northern Inner Mongolia and southern Outer Mongolia to the edge of Sinkiang (新疆).

The Great Khingan Mountains (大興安嶺山脈) form the tectonic boundary between Mongolia and Manchuria. Although, today, the Mongolia Plateau lies 1200–1500 m above sea level, it is said that at the end of the Carboniferous Period, the sea submerged the plateau and almost entirely covered it. Later, the sea receded forever, leaving only small remnants, such as Dalai-Nor, Kweitun-Nor, Artsakan-Nor, etc. Upon approaching the Heilung-Kiang (黑龍江), or Amur River, the Great Khingan sends a branch southeastwards known as the Little Khingan (小興安嶺山脈). Along the Korean border, the Changpai (長白山脈) and its chains run southwest to northeast as far as the

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(1) The ideas of the true steppe, low steppe, and desert, will be more clearly defined as we proceed.

Ussuri River is reached. When we come to Russian Territory, the Sikhota-alin forms the backbone of the Maritime Provinces, while along the coast of the Japan Sea, we find other mountains, such as the Yablonoi, lying northwestward near Chita, and the Stanovoi, marking the southern border of Yakutsk in U.S.S.R.

Factors of the Habitat

Every part of the environment, whether it exerts, directly or otherwise, a specific influence upon the life of the plant, is a factor of the habitat. The habitat is a complex in which one factor acts upon other factors and is, in turn, acted upon by them. The factors, however, may be conveniently grouped into four classes, according to the nature of the environmental conditions to which they give rise, namely, (I) climatic, (II) edaphic, (III) biotic (the effect of animals, including the whole of man's influence), and (IV) physiographic (topographical factors, etc.).

I. Climatic Factors

The climate over an extended area of land, such as a continent, being usually very diverse, the conditions for plant growth differ in corresponding manner. Distances from the ocean, differences in latitude and altitude, etc., all profoundly affect precipitation and temperature as well as other climatic factors. Vegetation responds by its distribution into groups, each of which is in close equilibrium with its particular climatic complex. The close relationship between climate and plant communities is so marked that most students of climate find vegetation itself the best indication and measure of the summation of the climatic factors. These questions will be referred to in greater detail under "Chimatic indicators".

For a better understanding of the climatic influences for plant growth we need, in addition to temperature and rainfall records, to know about the distribution of the precipitation throughout the different months of the year, whether the rains fall in torrents or slowly and evenly, the degree of humidity of the air for different seasons, the amount of sunshine and cloudy weather, the rate of evaporation of moisture from the land surface, and velocity, frequency, and direction of winds.

Formerly, in North China and southern Chahar (察哈爾), we owed our climatic data to the Catholic Mission Fathers, who had early started to collect data, many of their observation stations having been established for

years.[1] Russian observers were engaged climatic studies in Manchuria, before the Russo-Japanese War, 1904.

Since the foundation of Manchoukuo, 1932, stations have been established at important meteorologic points all over the country, while in the transition stage between the two foregoing periods, Russian observers in the northern part, mainly along the former Chinese Eastern Railway, and Japanese observers, in the southern part, mainly under the direction of the S. M. R. C., made their observations. In the Russian Territories, where a network of meteorological stations have been established, climatic studies of a national scope are conducted. But most of our knowledge of climatic condition in interior Asia, including the greater part of Inner and Outer Mongolia, Sinkiang (新疆), and Tibet (西藏) is purely qualitative, although the Sino-Swedish Expeditions under the leadership of Dr. SVEN HEDIN[2] have succeeded in collecting some quantitative data. Notwithstanding these drawbacks, generally speaking, the available literature covering the climate of these regions is fairly rich when compared with the reports, with which the writer has had to work, so that the data, in some respects, is helpful in his studies. But since these records were mainly obtained from the sole purpose of meteorology, unfortunately, their value for the student of vegetation is only of a general character. One of the chief reasons for this is that, except for a few special cases, meteorological stations are invariably maintained in connection with an institution located in a city, village, or even in a clearing, often at considerable distances from masses of natural vegetation. In addition to this, the instruments are placed at a certain standard height above the ground, so that they give little detailed information of the actual conditions that obtain in the immediate vicinity of the vegetation.

To remedy these objections, some recommendations have lately been made, one being the observation of micro-climate[3, 4, 5, 6, 7] in connection with natural

(1) Siwantse (西灣子) in Chahar is known as one of the oldest stations of this kind. The station, located in the Siwantse Seminary, is situated in a large valley of the Yin-Shan Mountains, near the Tanan-Shan, having the perfect weather records since the year 1880, except some blanks.

(2) HEDIN, S.: Across the Gobi Desert, (1931).

(3) YAPP, R. H.: On stratification in the vegetation of a marsh and its relations to evaporation and temperature. Ann. Bot. **23** (1909) 275–320.

(4) FILZER, P.: Untersuchungen über das Mikroklima in niederwüchsigen Pflanzengesellschaften. B. B. C. **55** (1936).

(5) LUNDEGÅRDH, H.: Klima und Boden. (1930).

(6) HATAKEYAMA, I., G. KUSE, M. MATUNO, K. TAKASU und T. YAMADA,: Mikroklima in einem Reisfeld (Japanisch). Agricul. & Horticul., **12** (1937) 2562–2572, 2807–2814, 3049–3063.

(7) KIHARA, H.: Biological investigations in Inner Mongolia (Japanese). Bot. & Zool., 8 (1940) 72–76.

vegetations, another the proposal to use phytometers,[1] that is, to measure the value of a factor, using standardised plants.

(A) **Mechanisms of climate**

Asia, occupying the greater part of Eurasia, is the largest continent, its interior being one of the earth's driest areas. For this reason, the air over the interior, Mongolia, Sinkiang (新疆), and Siberia, is much colder in winter than that over the surrounding oceans, the Pacific and the Indian, and warmer in summer. During the summer months, these differences in temperature between the two areas causes the heat to expand air over the interior to rise and overflow aloft toward the encircling oceans, where the added ocean air raises the barometric load. This process establishes a large-scale convectional circulation with a semi-permanent low pressure over the land and semi-permanent high pressure over the oceans. The reduced pressure over the interior resulting from this outflow then causes the warm moist oceanic air to be drawn in along the surface and fill the pressure deficiency in order to establish equilibrium. The summer monsoons, thus laden with moisture, upon being sufficiently cooled by meeting cold air masses in passing over hills and mountains, or by rising to the cooler upper strata, by convection, drop their moisture. All these phenomena result from the land surface rapidly radiating its heat, because soils and rocks have much lower specific heat values than water. During the winter, conditions are reversed, with cold, dry, descending and outblowing air over the continent and rising air over the oceans. No continent exhibits this circulatory system so strongly as Asia; the oceanic winds in summer that result from the operation of this system being called the summer monsoon and the continental winds in winter, the winter monsoon. In East-Asia, the latter monsoon is more strongly developed than the former, because the center of the summer low pressure area occurs at high altitudes and high latitudes, where the climate tends to be cooler than farther south and lower down. So the latter monsoon, the cold dry north-westerly winds in winter, are responsible for the scantiness of winter rain and snowfall and for the frequent dust storms, characteristic of the winters and springs of North China, Mongolia, and southern Manchoukuo. The climate, therefore, is essentially a monsoon climate, with a well-marked rainy season and a long intervening dry period, during which comparatively little

(1) CLEMENTS, F. E. and GOLDSMITH, G. W.: The phytometer method in ecology. (1924).

rain falls; this fact, as we shall see later, has an important bearing on the vegetation and on the ecological problems presented by its study.

Independent of these monsoon systems, the cyclonic storms are also responsible for a large share of the actual rainfall of Central and North China. The paths of these storms in China extend from west to east, between northern Kwantung (廣東) Province and Inner Mongolia.

Another element in the climate is the tropical typhoon. The wind velocity near the vortex often exceeds 40 meters a second, the storm as a whole moving forward at the rate of a few hundred kilometers a day. The typhoons of the western Pacific, originating east of the Philippines in the vicinity of the Marshall and Caroline groups, after moving west and then northeast, either strike the southeastern coast of China or recurve toward Japan before reaching the mainland. Typhoons are always succeeded by rain squalls. In contrast to the gentle spring rains that accompany the cyclonic storms, much of the summer rainfall of the southeastern provinces is derived from these tropical storms.

(B) Temperature

Temperature is of vital importance to plants because increased temperature increases the rapidity of every chemical action, on which the life processes of plants ultimately depend.

While the temperature of the plant tends to follow closely that of its environment,(1) unlike warm-blooded animals, plants are not endowed with temperatures that are independent of the surrounding medium, although there are certain notable exceptions to this rule. The temperature of the plant, especially those of the stems and leaves, may be 10 to 15° C higher than that of the air.(2) With sudden changes in temperature, the plant responds more slowly than air, its temperature for a time being either higher or lower. This is due to the abundance of water and its high specific heat. At any rate, the activity and growth of any plant depends upon its receiving the necessary amount of heat during the growing period. But since all temperatures below

(1) Certain plant activities, notably respiration, evolve heat, but even when the vital processes are most vigorous, a marked rise in temperature is prevented by outward conduction and radiation. In this way, the cover, whether dead or alive, is more indispensable for realization the marked higher temperature than that of the surrounding medium by conserving heat inward.

(2) CLUM, H. H.: The effect of transpiration and environmental factors on leaf temperatures, I. Transpiration. Amer. Jour. Bot., 13 (1926) 194–216.

the minimum are ineffective in promoting growth, it is first necessary to select a plant zero, i. e., a temperature above which growth begins.(1) The plant zeros most used have been 6 and 4.8° C.

From the variations in the growth rate of plants, the efficiency index for each degree of temperature between 3 and 57.5° C was calculated. For example, the value at 3° C for corn seedlings is 0.1; at 4.5° C it is 1.0; and at 14° C it is 16.1. At 31.5° C it reaches a maximum of 122.3 and falls again at 57.5° C to 0.1. This method is promising as a laboratory experiment and as the basis for ecological investigation.(2)

Thus in many cases, the growth of annuals are limited by temperatures of the growing season alone, while in others, such perennials as grapes or teas, are especially limited by temperatures of the nongrowing season as well.(3)

(1) **Lower lethal temperature.**—With decrease in temperature to a certain minimum, growth in size is retarded; at lower temperatures, cell division and photosynthesis are also checked, while at a still lower minimum, respiration ceases and death results.(4)

The minimum temperature, moreover, varies greatly with the time of the year and with different conditions of the plant as well as with the results of its previous experience with low temperatures. The chief difference lies in the amount of water the plant contains.(5) The watery leaves and herbaceous stems of plants of temperate climates, for example, are usually killed by exposure to 0° C and frequently at temperatures of from 2 to 4° C above freezing.(6) The dried seeds and the inactive parts underground resist the prolonged effects of temperatures of from –30 to –40° C, dry seeds being uninjured at from –193 to –250° C.(7)

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(1) KINCER, J. B.: The relation of climate to the geographic distribution of crops in the United States. Ecology, **3** (1922) 127–133.

(2) LIVINGSTON, B. E.: Physiological temperature indices for the study of plant growth in relation to climatic conditions. Physiol. Res., **1** (1916) 339–420.

(3) SHREVE, F.: The role of winter temperatures in determining the distribution of plants. Amer. Jour. Bot., **1** (1914) 194–202.

(4) ZACHAROVA, T. M.: Über den Einfluss niedriger Temperaturen auf die Pflanzen. Jahrb. f. wiss. Bot., **65** (1925) 61–87.

(5) MEYER, B. S.: Further studies on cold resistance in evergreens, with special reference to the possible rôle of bound water. Bot. Gaz., **94** (1932) 297–321.

(6) SELLSCHOP, J. P. F. and S. C. SALMON,: The influence of chilling, above the freezing point, on certain crop plants. Jour. Agric. Res., **37** (1928) 315–338.

(7) LIPMAN, C. B. and G. N. LEWIS,: Tolerance for liquid-air temperatures by seeds of higher plants for sixty days. Plant Physiol., **9** (1934) 392–394.

Owing, moreover, to the fact that the water in the tissues, instead of ever being pure, always contains various substances in solution which lower the freezing point below 0° C, plants, instead of freezing at this temperature, do so only at some lower point. Abundant sugar, resins, and especially fatty oils, which are characteristic of many arctic or subarctic trees (conifers, birches), may lower the freezing point very considerably.(1) Many plants can stand freezing, provided the freezing and thawing are slow.(2) But rapid thawing, particularly, is likely to be fatal, apparently owing to sudden rupture of the tissues by melting of the contained ice.

Certain arctic and alpine plants which may produce their flowers after pushing themselves through banks of snow, may continue to flourish, although the temperature falls below frost every night.(3) The activities of marine algae at temperatures below zero have been mentioned. On the other hand, the growth of many tropical plants is retarded at 20° C, and frequently killed at 10° C. Protection by dead surface tissues, such as corky bark, because of their slow conduction of heat, tends to slow down these processes.(4, 5) When plant tissues freeze, water is withdrawn from the cells much as is done when they wilt, and crystals of ice are formed in the intercellular spaces. After equilibrium is established between the force of crystallization and the water-retaining power of the cell at any temperature, no more water freezes unless the temperature goes lower.(6)

The amount of water retained in the liquid state by solutions of different concentrations at various temperatures may be easily calculated if account is taken of the freezing point of the corresponding concentration. The following table gives us an idea of what will occur with solutions of other concentra-

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(1) SCARTH, G. W. and J. LEVITT, : The frost-hardening mechanism of plant cells. Plant Physiol., **12** (1937) 51–78.

(2) STUCKY, I. H. and O. F. CURTIS, : Ice formation and the death of plant cells by freezing. Ibid., **13** (1938) 815–833.

(3) WINKLER, A. : Über den Einfluss der Aussenbedingungen auf die Kälteresistenz ausdauernder Gewächse. Jahrb. f. wiss. Bot., **52** (1913) 467.

(4) NIGHTINGALE, G. T. : Effects of temperature on metabolism in tomato. Bot. Gaz., **95** (1933) 35–58.

(5) ——: Effects of temperature on growth, anatomy, and metabolism of apple and peach roots. Ibid., **96** (1935) 581–639.

(6) WIEGAND, K. M. : Some studies regarding the biology of buds and twigs in winter. Ibid., **41** (1906) 373–424.

Table 1. Correlation between initial condition of the solution and the amount of water changing into ice at a given temperature (after ÅKERMAN).

Temperature C°	Amount of water changing into ice in % at the initial concentration:				Final concentration of solution
	1/4 normal	1/2 normal	normal	2 normal	
−0.46	traces	—	—	—	1/4 normal
−0.93	50.0	traces	—	—	1/2 „
−1.86	75.0	50.0	traces	—	1 „
−3.72	87.5	75.0	50.0	traces	2 „
−7.44	93.8	87.5	75.0	50.0	4 „
−14.88	96.9	93.8	87.5	75.0	8 „

tions at different temperatures.(1) It seems almost certain that death is not due to cold,(2) but to the results attending this process of desiccation.

In northern latitudes, most evergreen trees, shrubs, and herbs, with lowering of temperature, convert their reserve supply of starch into fats and oils.(3) This also occurs in certain deciduous trees like the birch. It is well known that water in the presence of fatty oil in the form of an emulsoid may be greatly undercooled before ice forms. Besides, in many cases, an abundance of sugar occurs in the cell sap.(4, 5) Pentosans, mucilages, and pectic bodies, which have a high water-retaining power, being abundant in many plants, further diminish the danger from desiccation and consequent death.(6) Cell permeability seems also closely correlated with hardening against frost or

(1) MAXIMOV, N. A.: Physiologisch-ökologische Untersuchungen über die Dürresistenz der Xerophyten. Jahrb. f. wiss. Bot., **62** (1923) 128–144.

——: Wilting of plants in its connection with drought resistance. Jour. Ecol., **12** (1924) 95–110.

(2) ILJIN, W. S.: The point of death of plants at low temperatures. Protoplasma, **23** (1935) 288–289.

——: Über den Kältetod der Pflanzen und seine Ursache. Ibid., **20** (1933) 105–124.

——: Über die Austrocknungsfähigkeit des lebenden Protoplasmas der vegetativen Pflanzenzellen. Jahrb. f. wiss. Bot., **66** (1927) 947–964.

(3) TUTTLE, G. M.: Induced changes in reserve materials in evergreen herbaceous leaves. Ann. Bot., **33** (1919) 201–210.

(4) GAIL, F. W.: Osmotic pressure of cell sap and its possible relation to winter killing and leaf fall. Bot. Gaz., **81** (1926) 434–445.

(5) LEWIS, F. J. and G. M. TUTTLE: Osmotic properties of some plant cells at low temperatures. Ann. Bot., **34** (1920) 405–416.

(6) HOOKER, H. D.: Pentosan content in relation to winter hardiness. Proc. Amer. Soc. Host. Science, (1920) 204–207.

drought resistance.[1, 2, 3] During freezing, or as a result of freezing, sucrose may be changed to the reducing sugars with consequent increase of osmotic efficiency.[4] The presence, moreover, of these nonelectrolytes in the cell diminishes the tendency to precipitate proteins.[5]

Withdrawal of water from the cell results in greater concentration of the salt within. Certain proteins are precipitated in strong salt solutions, and it is generally believed that the chief cause of injury or death by freezing is the precipitation of proteins from the desiccated protoplasm, although some regard the injury as mechanical, due either to the pressure of ice or to stress set up by displacement of the water.[6, 7]

In short, three ways of protecting the plant from death by freezing are conceivable, by preventing fall of temperature in the plant itself through reduction in the heat conductivity of the external parts of the plant, or by preventing fall of the freezing point of the cell sap by means of increase in its concentration, or finally, by diminishing the injurious consequences of freezing with the aid of certain chemical changes either in the cell sap or in the protoplasm of the freezing cells.

(2) **Higher lethal temperature.**—High leaf temperature, resulting either from intense insolation or high air temperature, or both, may result in a relative high rate of water loss through transpiration or simple evaporation. In extreme cases, particularly at times when the rate of absorption of water is sluggish, entire plants are killed in this way.

In other cases, relatively high temperature often induces various types of

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(1) LEVITT, J., G. W. SCARTH and R. D. GIBBS,: Water permeability of isolated protoplasts in relation to volume change. Protoplasma, **26** (1936) 237–247.

(2) SCARTH, G. W.: Estimation of protoplasmic permeability from plasmolytic tests. Plant Physiol., **14** (1939) 129–143.

(3) STRAUSBAUGH, P. D.: Dormancy and hardiness in the plum. Bot. Gaz., **71** (1921) 337–357.

(4) MAXIMOV, N. A.: Internal factors of frost and drought resistance in plants. Protoplasma, **7** (1929) 259–291.

(5) NEWTON, R. and W. R. BROWN,: Frost precipitation of proteins of plant juice. Canadian Jour. Res., **5** (1931) 87–110.

(6) LEVITT, J. and G. W. SCARTH,: Frost-hardening studies with living cells. I. Osmotic and bound water changes in relation to frost resistance and the seasonal cycle. Ibid., **14** (1936) 267–284.

——: Ibid., II. Permeability in relation to frost resistance and the seasonal cycle. Ibid. **14** (1936) 285–305.

(7) SCARTH, G. W. and J. LEVITT,: The frost-hardening mechanism of plant cells. Plant Physiol., **12** (1937) 51–78.

metabolic disturbances detrimental or even fatal to plants, an important example of which is respiration. The general principles governing the effect of temperature on the rate of respiration are illustrated by the data shown graphically in FERNANDES' paper.(1) That is, in his experiment with pea seedling at temperatures ranging from 0 to 25° C, increase in temperature resulted in increase in the initial rate of respiration. At temperatures exceeding approximately 30° C, respiration showed a decrease with time, which became more marked the higher the temperature. One probable explanation is that this effect is due to progressive intense inactivation of enzymes with increase in temperature. Another is that carbon dioxide may accumulate in the cells in such concentrations at high temperatures as to check the rate of respiration. Obviously in the case of some plant, it is clearly higher than the values obtained in this experiment, while for others it is lower. A relatively high temperature therefore frequently causes stunting of plants because a disproportionate amount of the foods manufactured is consumed in respiration, the maintenance of which condition for an extended period often kills the plants. Although, these indirect thermal effects are very serious, direct thermal effects on the protoplasm are far oftener fatal to plants.

In the neighbourhood of 40° C, changes begin to occur in the protoplasm, which are inimical to its maintenances as a working organ, 45° C being already a lethal temperature for many of the higher plants,(2) so that this maximum temperature seems to be the inherent qualities of the protoplasm, such as its coagulation. On the other hand, however, such temperatures are also very closely related in their natures to alterations in the water relations. It is least resistant in the active condition, when the tissues are filled with water, and most resistant in the resting state, typical of spores, seeds, etc. When dry, seeds can endure temperatures above 100° C, although, if water-soaked, they are readily killed at 70° C.

In a forest, which has been swept by a ground fire, it is usually noticeable that some of the trees have escaped injury, while others have been killed. Of individuals of the same species, older trees are more likely to survive than

(1) FERNANDES, D. S.: Ärobe und anärobe Atmung bei Keimlingen von *Pisum sativum*. Rec. Trav. Bot. Nèerland, **20** (1923) 107–256.

(2) Numerous algae and bacteria thrive in hot springs at a temperature as high as 77° C and a few fungi can endure a temperature of 89° C. Certain species of yeasts have been shown to be capable of enduring a temperature of 114° C when dormant, and bacteria in the spore condition are able to withstand temperatures of 120 to 130° C.

the younger ones. In mixed stands pines are more likely to escape injury than hardwoods (in this case respective root-sprouting ability is out of question). These differences in susceptibility to injury from ground fires are apparently correlated with the thickness of the bark layer.

(3) **Temperature variations in habitat.**—The maximum daily temperature does not occur at noon "sun time", as in the case of light, but somewhat later, often about 2 to 3 p. m. The minimum is not reached at midnight, but just before sunrise the following morning.

Variations in temperature occur with changes in latitude and altitude. Since high latitudes receive the sun's rays at a greater angle than at the equator, absorption of heat by the atmosphere is correspondingly greater. In so far as absorption is concerned, high mountains receive more heat than lowlands. Loss by radiation, however, being so much greater, mountainous regions are uniformly colder than plains or lowlands lying on the same parallel. This is due to the rarity of the air, which allows heat to pass through it readily. Although the air on mountain summits is colder than that of the plains, the surface temperature of the soil is often considerably higher. This depends partly on the swift air-circulation on the summits. Ordinarily, the air is warmer in the daytime than the soil at the same place, especially on sunny days. It loses heat more rapidly, however, and after a sudden decrease in temperature or at night, the soil for a time is usually warmer than the air. That is, heat penetrates the soil slowly, either on account of poor conductivity or because of the great capacity of the water for latent heat.

Given adequate precipitation, the effect of temperature manifests itself in the luxuriance of the forest. Generally speaking, the height, density, variety of species, and rate of growth of the forest components all fall off with lowering temperature. But the needle-leaved trees react somewhat differently from broad-leaved trees, reaching their highest development in comparatively lower climates, where they surpass the broad-leaved species. In ascending mountains, we find that with increasing cold, winter-deciduous species become prevalent, while at the tree limit the forest gradually degenerates to scrub form, where, however, hard-leaved evergreens, such as species of *Rhododendron*, predominate. Thus the effect of temperature is best demonstrated by the altitudinal zonation seen in mountainous regions, where the different species and types of forest occupy definite belts according to elevation.

Temperature also varies with slope. This is due to the fact that a square decimeter of sunshine covers this extent of surface only when the rays strike

at right angles. For instance, at an angle of 10° a square decimeter receives but 17 per cent as much heat as at 90°, for which reason the timber line is often 300 meters (or more) higher on the southern than on the northern slopes, whence it comes about that in mountainous regions, forest communities, whose upward extension is directly limited by temperature, may be found at much higher elevations on the warmer slopes.(1, 2) In general, the larger the mountain mass and the higher the mountains the greater the altitude to which the tree limit attains.(3, 4) In the same way, the timber line is profoundly modified by the effects of cold-air drainage, as a result of topograghy.

A well-marked local temperature effect is also known in the basin on the upper reaches of the Amur or in the Gobi Desert, into which the heavier cold air mass sinks to settle, which air mass, interrupted by surrounding mountains, is not free to flow out into the Pacific Ocean or the Hwang-Hai (黃海). Since, on the other hand, in the Manchurian Plain or in the lowland along the Usuri, the cold air mass freely drains from the north to the south, any place that is exposed to these cold air masses, like Vladivostok and Newchwang (牛莊), has a comparatively colder temperature, sometimes limiting the distribution of particular species or communities that flourish on neighbouring hilly lands, like Kirin (吉林) or Muling (穆稜). The best examples are seen in the distributions of *Prunus Leveilleana* KOEHNE.

Temperature affects vegetation locally also largely through the soil. So long as the water supply remains sufficient, a warm soil stimulates root absorption.(5) Heavy wet soils warm up slowly and retard the development of vegetation.(6) It is readily seen that measurement of soil temperature, which affords the simplest means of determining the qualities of the site and the length of the growing season as determined from soil temperatures, is a fairly

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(1) PEARSON, G. A.: Factors controlling the distribution of forest types. Ecology, **1** (1920) 139–159, 289–308.

(2) SHREVE, F.: Soil temperature as influenced by altitude and slope exposure. Ecology, **5** (1924) 128–136.

(3) QUERVAIN, A. de,: Die Hebung der atmosphärischen Isothermen in den Schweizeralpen und ihr Beziehung zu den Höhengrenzen. Gerlands Beitr. z. Geophys., **6** (1903) 4.

(4) BRAUN-BLANQUET, J.: Pflanzensoziologie, (1928) 223.

(5) TAGAWA, T.: The influence of the temperature of the culture water on the water absorption by the root and on the stomatal aperture. Jour. Facul. Agr., Hokkaido Imp. Univ., Sapporo, **39** (1937) 271–296.

——: Further studies on the influence of water temperature on water absorption and the stomatal aperture. Ibid., **40** (1938) 1–33.

(6) DÖRING, B.: Die Temperaturabhängigkeit der Wasseraufnahme und ihre ökologische Bedeutung. Zeitschr. f. Bot., **28** (1935) 305–383.

accurate basis, especially in mountainous regions, for determining the tree that should be grown on that site.(1)

In regions where the soil is permanently frozen at a certain depth,(2, 3) the surface soil thaws out in the spring, often supporting a luxuriant vegetation during the summer. The temperatures of the layers of soil above the bottom ice at different periods during the thawing process and through the growing season, would be of great interest in connection with a study of the distribution in depth of the root systems, since they surely must limit the character and development of the vegetation.(4)

But for the high alpines of equatorial regions, whose summits have eternal winter and no summer, even in the coldest regions on earth, the temperature in summer always rises well above the limits at which growth is possible, although it may be only for a period of a few weeks. This short growing period excludes many species that lack the time to build up enough organic material to flower and ripen their seeds—for instance, it excludes all the annual plants.

Generally speaking, the temperature of the plants' own habitat is most favourable for its development. For tropical plants, air temperatures above 32° C are most favourable. Most temperate plants attain their highest development between 15 and 32° C, while arctic and alpine species may grow at temperatures only slightly above the freezing point. Under these circumstances, maximum or minimum temperatures may directly operate in preventing the extension of plant ranges, but in a number of cases the fact that most plants have their own optimum temperature ranges for their wellbeing outside of which range the plant is less vigorous in development and propagation, is the most decisive factor in the formation of plant communities. Thus, since the plant may be at a disadvantage in competition with others already well established, it is sooner or later defeated in the severe struggle for existence.

This being the case, the great climatic vegetational zonations of the world

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(1) BATES, C. G., F. B. NOTESTEIN and P. KEPLINGER,: Climatic characteristics of forest types in the central Rocky Mountains. Proc. Soc. Am. For. **9** (1914) 78.

(2) SCHOSTAKOWITSCH, W. B.: Der ewig gefrorene Boden Siberiens. Z. Ges. Erdk. Berlin, (1927) 394.

(3) The ranges of the permanently frozen areas in the regions under consideration are seen in the map on P. 484.

(4) The depth of the root systems is intimately related to the uprooting of trees by the action of strong winds.

and of high mountains depends primarily on temperature, whence species are sometimes classified into megatherms, mesotherms, and microtherms, in accordance with this relationship.

(4) **Temperature recorded.**—Mean annual temperatures, practically speaking, have less value for the student of vegetation, because they take no account of season. For instance, in parts of the Siberian forest region, where the short summer is hot and produce a luxuriant herbaceous vegetation, besides being sufficing for the growth and reproduction of the trees, the mean annual temperature is $-15°$ C, i. e., very much below the minimum at which any vegetation could thrive at all. Of all the data commonly published, the most useful are the actual daily maxima and minima during certain selected periods, especially at the beginning, the middle, and the end of the growing season. As already mentioned, the yearly maximum and minimum temperatures are also very important factors in the development of vegetation, since plants, particularly cultivated crops, may be damaged by a few hours of excessive heat or killed by a brief period of low (usually freezing) temperatures.

For a serious study of the temperature relations of a plant community, a thermograph should be set up in the field, while in the case of a highly stratified community, such as a forest, more than one will be required, because the temperatures and temperature variations of different strata may differ widely. As to soil temperatures, ordinarily, only the surface layers to the depth of a few centimeters are likely to be of much importance, since changes in temperature rapidly flatten out on descending into deeper layers. The highest temperatures are usually found at the soil surface.

In going through the regions under consideration from the southeast to the northwest, the climate becomes more and more typically continental, the temperature range between day and night as well as between summer and winter being very wide. The difference between summer and winter temperatures increases with latitude, while that between day and night is more marked in summer than in witer, a difference of as much as 40 degrees being not uncommon in the heart of Asia. The yearly mean temperature ranges from $-10°$ C in the north (the Amur Province, Soviet Union) to $10°$ C in the south (Shantung (山東) district). Even in the south, during the five months from November to May, the mercury never rises above $10°$ C, descending in the cold season to as low as $-10°$ C, beginning to rise again usually about April. During the three months of May, September, and October, the temperature is from 10 to $20°$ C, while the three months of June, July, and August form

the hot season, in which the temperature fluctuates between 20 and 40° C. In the Shantung district, the first frost comes about the middle of November and the last early in March, while in the Amur Province, they come at the beginning of September and towards the end of May respectively. The approximate length of the growing season therefore works out to from 90 days in the north (Amur Prov.) to 250 days in the south (Shantung dist.). Consequently, in the north, the crops and annual herbs, generally, have to complete their growth, bloom, and fructification within the short season of 90 days. But the fact that the season, though short, is comparatively hot and that the hours of sunshine are long, seems to be very favourable for plants. A plant, therefore, so long as it is early ripening, can flourish much farther north than it could be expected to do in Japan. The cultivation of rice in northern Manchoukuo is a good example.

Owing to publication of diagrams obtained by the writer illustrating the local variations in monthly mean temperatures and precipitations being prohibited by the authorities, except some examples of the well-known weather records, which will be illustrated in Fig. 3, all other data are lacking in this paper.

(C) Precipitation

In all habitats except those, where the sppply of water is constant owing to the presence of springs, streams, ponds, or other bodies of water, the dependence of water content upon precipitation is absolute. Precipitation occurs in various forms, such as rain, hail, dew, frost, and snow, of all which, rain is the most important.

(1) **Rain.**—The extent to which rain replenishes soil water is not necessarily in proportion to the amount that falls. Light rains falling on a warm, dry soil are totally converted into vapour within a few hours, with no effect on the water content of soil.(1) For example, the effect of 100 mm of rain in a given month will differ decidedly if the fall is approximately 3 mm every day, or if, on the other hand, the falls on each of four successive days are 12 mm and the other days are rainless. Since, in the former cases, it has little or no effect on the soil, the amount alone of annual rainfall is not only of great importance in determining the type of vegetation over wide areas, but also its frequency and the season of the year during which the rainfall

(1) SHREVE, F.: Changes in desert vegetation. Ecology, **10** (1929) 364–373.

occurs. That is, a plant community changes its aspect in various ways according to the amount of rain it receives, its duration, and seasonal frequency.

Although a rainfall map of East-Asia corresponds much more closely to the distribution of standard types of plant communities(1) than does a temperature map, the total amount of rain that falls in a year is not such a good guide to vegetation as has been generally expected. Over the greater part of the North China Plains, the average annual rainfall is enough to insure the production of crops, but the uncertainty in regard to the distribution of the rainfall makes crop production hazardous. In Manchoukuo the distribution of forest, except in the case of swamp-forest, is bound up considerably with the climate, especially with the average annual rainfall and the number of rainy days, the effect of which, however, is greatly modified by frequent high winds and a porous soil, such as loessial soil.

In the mountain regions of eastern Manchoukuo and the Russian Maritime Province, where the rainfall is heavy and the humidity great, the forest trees are more luxuriant in character than they are under drier conditions prevailing in the mountains of North China, the individual species being mostly different. As moisture conditions become less favourable with the same temperatures, the forest falls off in density and in richness in species. In still drier climates, the heights of the trees also become less, thorny trees become more abundant, and xerophytic adaptations become increasingly prevalent.

Rainfall during the growing season, when temperatures are high, acts very beneficially in causing organic matter in the soil to decay, thus increasing the available nutrients. Where the rain, although most of it falls in the late autumn and winter, is sufficient in quantity, but there is a hot dry summer, the vegetation being of the evergreen sclerophyll type. On the other hand, increase of total rainfall and a more moist atmosphere with similar temperatures tend to replace the sclerophyll with a larger-leaved evergreen type of subtropical or temperate evergeen forest. Should the rainfall be fairly abundant, but not sufficient to support a forest, the grasses being taller and more mesophilous (true prairie type), whereas should it be scanty, the grasses are dwarfed and more xerophilous (true steppe or low steppe type). The greater temperate prairie and steppe regions of the world—the true grasslands (or

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(1) The standard types of plant communities will be referred to under appropriate headings later (Standard Formation in the regions under consideration).

the climatic grasslands)—have a preponderant early summer rainfall. With further decrease in the rainfall, we get the desert.

In short, the relation between amount of rain and kind of vegetations may generally be stated as follows: (I) much rain in winter and little in summer results in preponderence of evergreen shrubs, whereas the converse, (II) little rain in winter and much in summer causes the herbs to dominate, while (III) little rain both in summer and winter results in a desert, and (IV) reasonable rainfall both in summer and winter brings about a typical flourishing forest.

From the foregoing relationship between plant life and rain it will easily be seen that the case of the regions under consideration at large corresponds to (II) or (III) facts, except North and East Manchoukuo, and Russian territory, indicating that rainfall there is one of the most important factors in deciding the dominant vegetation. Then, rain, by washing away the humus and surface soil, allows the ground to solidify, rendering ventilation and filtration difficult, thus indirectly hindering plant growth. It also washes away seeds and seedlings, besides mechanically damaging young branches and leaf-surfaces. All this may be observed in the heavy rains, which is a notorious feature in

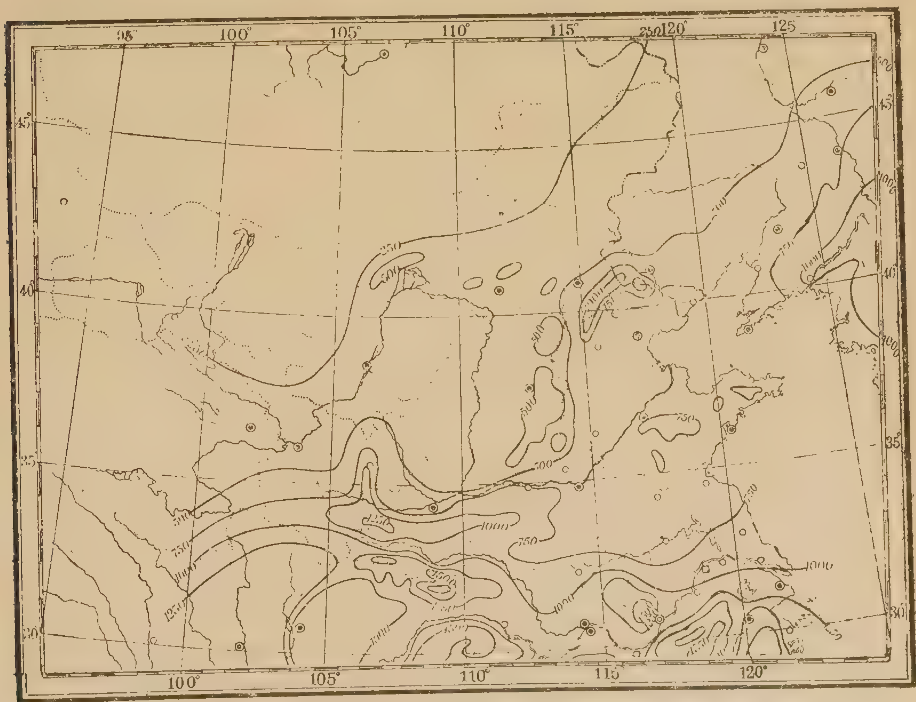


Fig. 2. Annual distribution of rainfall in the regions under consideration.

the summer of North China and its border lands belonging to Mongolia, especially on loessial plateaus and in mountainous regions, where the particular topography enhances the harm done to plants. Owing to the seasonal nature of the rains and the absence of a forest cover on the mountains, streams fluctuate widely in their flow. During most of the year their courses may be dry, while a heavy rainfall may result in torrential flood for a few days.

From the standpoint of physiological botany, probably the most ideal condition is that the soil by timely rainfall shall always retain suitable moisture for plants, but since, in reality, such a condition cannot be expected in the world of things, it must be said that, generally, frequent rainfall is the favourable condition for plant growth, particularly during their growing seasons. At all events, vegetations in North China, southern Manchoukuo, and Mongolia are not immune to lack of water, which drawback worsens as one goes north or north-west.

(2) **Rainfall recorded.**—As shown in the preceding section, the monsoons carry a certain amount of moisture to the neighbourhood of the southern or southeastern borders of Mongolia. And generally speaking, the amount of the induced rainfall decreases from the southeast to the northwest until the great deserts are reached, as shown in Fig. 2.(1) But beyond Yin-Shan (陰山) northward across Inner Mongolia, this inclination rapidly accelerates, desert conditions prevailing over the northern part of Inner Mongolia and much of southern Outer Mongolia.(2) On the other hand, northern Outer Mongolia receives slightly more moisture, and the cooler climate conditions make the moisture more effective for supporting vegetation and for developing soils.

It is not so much the scarcity of rain that makes Mongolia so barren and so hopeless from the vegetation standpoint, but its distribution. Sometimes in spring or in summer, the rain falls in torrents. The data clearly indicate that North China, especially the northern part, depens not noly on rainfall confined largely to the summer months, from June to the beginning of September, but also on the few days of heavy fall during those months. From year to year, the rainfall is also erratic. During July, 1917, for exemple, the rainfall in Siwantse (西灣子) was 230 mm, and in 1920, during the same month,

(1) The decreasing rate between Shanghai (上海) and Tientsin (天津) becomes quite marked along the Tsingling (秦嶺) and its mountain chains.

(2) For instance, the annual precipitation in Kashgar (喀什噶爾), Sinkiang (新疆) does not exceed 100 mm.

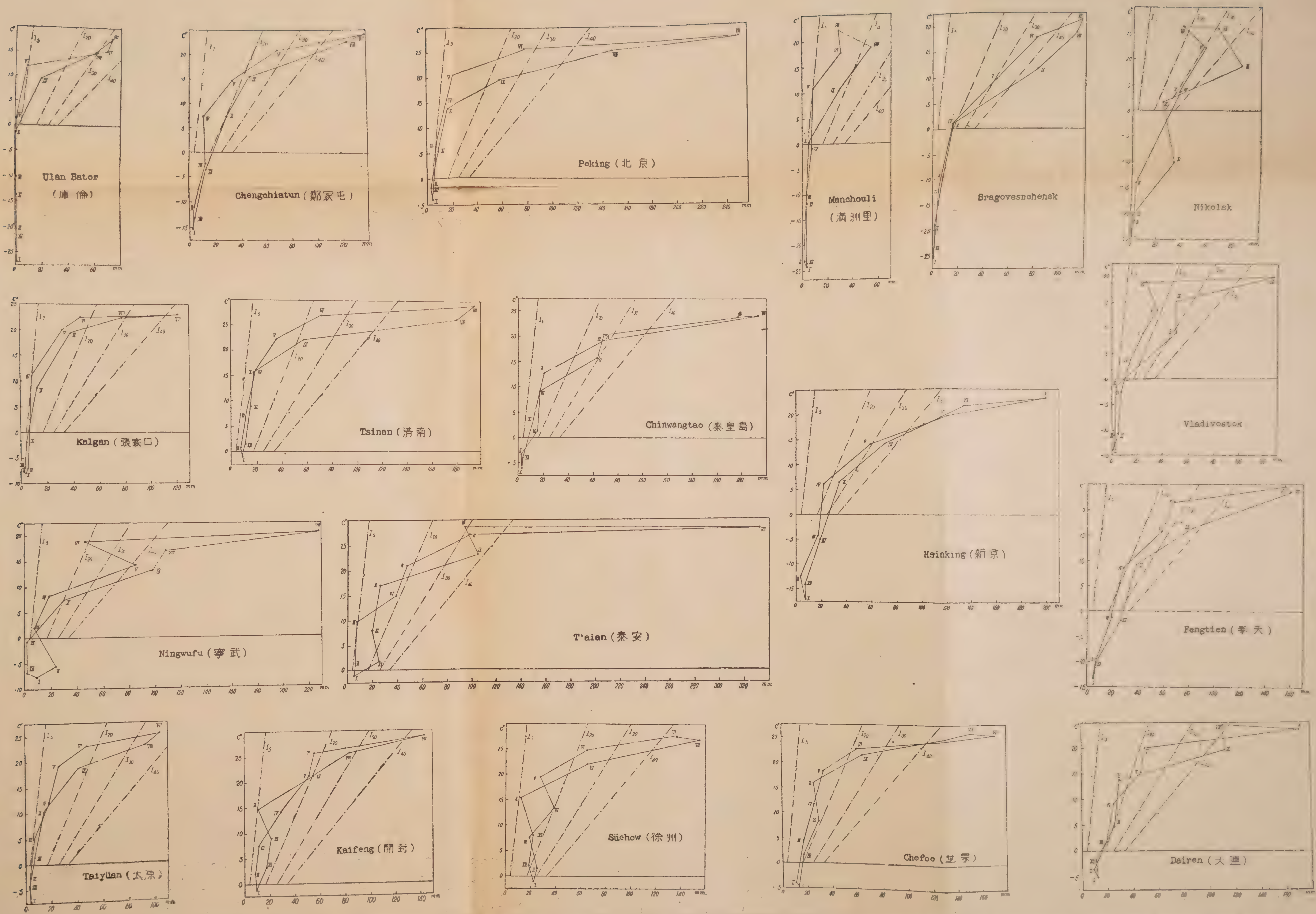
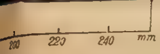
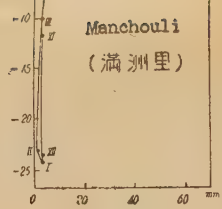
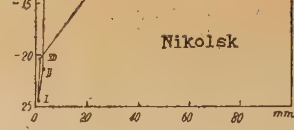
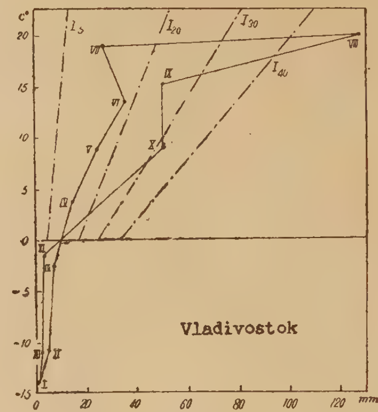


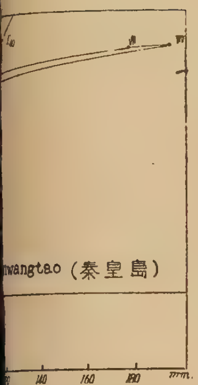
Fig. 3. The writer's new climatological diagrams, the hythergraph, which are based upon graphical presentations of temperature and precipitation locally recorded as monthly means. This is done for the twelve months of the year, these points then being connected by lines. I_5, I_{20}, I_{30} and I_{40} are delimiting of the corresponding vegetation types when MARTONNE's index of aridity (of which will be mentioned in P. 451.) are 5, 20, 30, and 40 respectively. So the discussion of these two kinds of figures reveal that there is a definite pattern exhibited for each vegetation type studied.

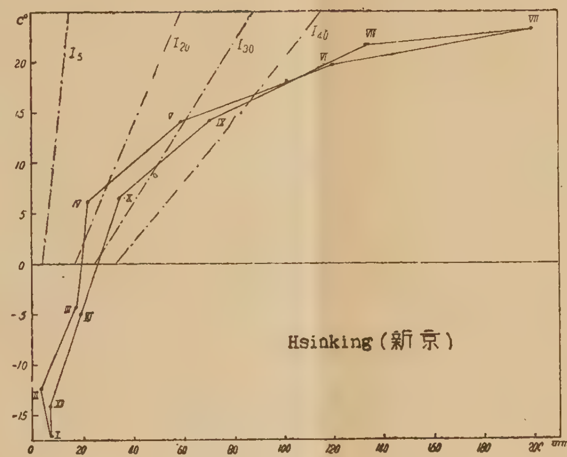


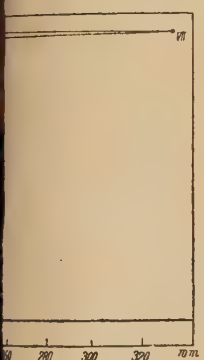


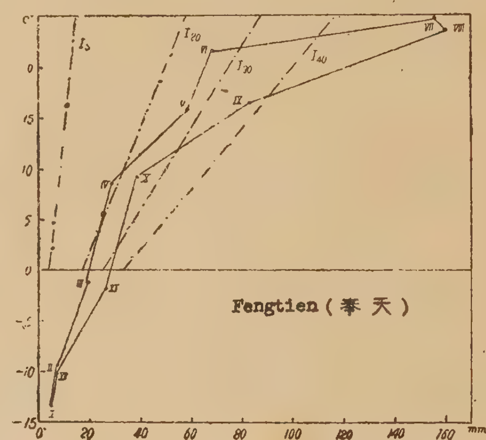


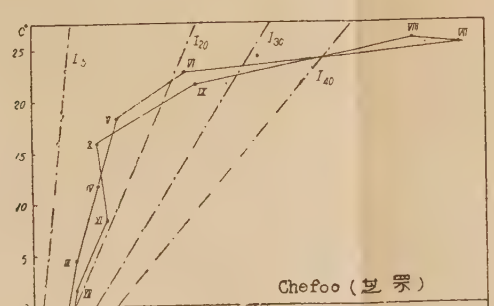


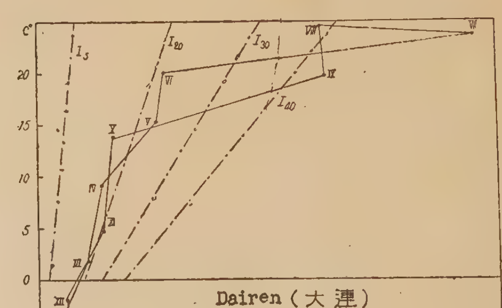












ature and precipitation locally recorded as monthly means. This is done for the twelve months of the year, these points then
dity (of which will be mentioned in P. 451.) are 5, 20, 30, and 40 respectively. So the discussion of these two kinds of figures

only 22 mm. As a rule, the less the precipitation, the greater the variation from year to year. But, in average years, generally speaking, excepting local variations, approximately two-thirds or three-fourths of the annual precipitation falls during the summer months, and only approximately one-twentieth of the annual total falls during the winter months. Even the heaviest precipitation, such as in the vicinity of the Hakutosan (白頭山) or the Tsinling (秦嶺), scarcely exceeds one-half that in Japan proper, falling off rapidly as one goes northwestward to the Gobi Desert, where it is only one-tenth of that in Japan.

(3) **Compound factors of temperature and rainfall.**—Any factor of habitat can be effective only when the others also act sufficiently. A soil may be highly nutrient, yet the nutrient substances are ineffective if moisture is lacking. Neither the sun nor water can accomplish anything if there is no nutriment. The minimum factor decides, so that a classification can not be founded on a single factor, nor on only a few factors. A single factor, moreover, acts differently according to other factors that accompany it. For example, 50 centimeters of rainfall act hygromorphically in oceanic regions but xeromorphically in the continental regions. Temperature modifies the moisture factors. The law of minimum is valid for natural plant communities.

Thus factors not only modify other factors, they may even replace them. Replaceability of factors is very important. It makes it possible for a vegetation to thrive in localities where various factors have changed, and this allows the spreading of plant communities. A locality is judged differently, according as we emphasize the changed or the unchanged factor. The vegetations should primarily be grouped, based on a few climatic factors, especially on temperature and precipitation. They should then be subdivided from the viewpoint of edaphic factors.

It is for these reasons that de MARTONNE's index of aridity $\left(\frac{P}{T+10}\right)$(1)

(1) MARTONNE, EMM., de.: Aréisme et indice d'aridité. Comptes Rendus, **182** (1926), 1935.
——: Regions of interior basin drainage. Geogr. Rev. **17** (1927) 397.
The indices of aridity in de MARTONNE's sense may be briefly summarized as follows:
0–5: complete areism, desert, no vegetation (desert region).
5–10: endoreism, dry climate, on the border of the desert, vegetation very poor (semi-desert region).
10–20: temporary run-off of water, no areism but endoreism or exoreism, according to the relief (steppe or savannah region).
20–30: prairies on best irrigated parts (leso-steppe or prairies).
30–40: good run-off (prairies region).
more than 40: run-off very abundant (forest region).

has been recognized as having several merits. The formula is a fraction whose numerator gives the total annual rainfall, in millimeters, while the denominator is the mean temperature of the year, in centigrade, the number 10 being added to the denominator to avoid negative numbers.

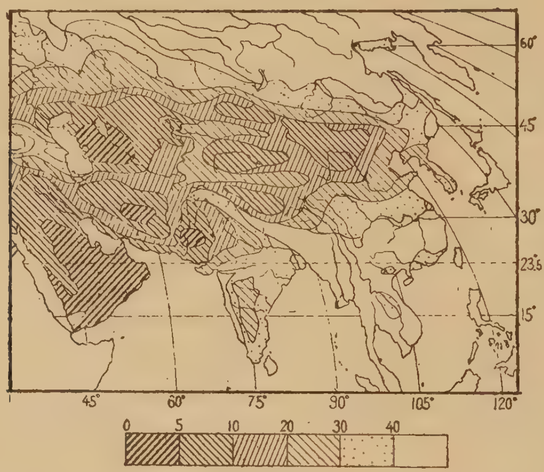


Fig. 4. Distribution map of MARTONNE's index of aridity in Asia. (after MARTONNE)

The Indexes of aridity computed by the writer for various localities in the regions under consideration will be seen from Table 2.

(4) **Snow.**—The most important effects of snow in climates where it falls regularly and lies until spring are (I) its function as a cover with which it protects low-growing plants from wind and often from serious freezing of the surface soil,(1) even if the soil at considerable depth is permanently frozen, and (II) as a reservoir of water for vegetation at the spring melting, besides acting in lieu of a copious spring rainfall.(2) The rapid development of spring vegetation in climates with heavy winter snow-lie is largely determind by the water supply from the melting snow.(3) Prolonged snow-lie, of course, acts in another way, i. e., it seriously shortens the growing season, so that but few species (or in the extreme case none) can establish themselves. Mechanical

(1) The best example is the cultivation of *Prunus Leveilleana* or *Fragaria chiloensis* var. *ananassa* BAILEY without any artifitial cover in Kirin (吉林).

(2) The forests of the North China mountains, such as those near Ningwufu (寧武), seem to be benefited considerably by the melting snow during a spring drought.

(3) HARSHBERGER, J. W.: Preliminary notes on American snow patches and their plants. Ecology, **10** (1929) 275–281.

Table 2. Indexes of aridity computed by the writer for various localities in the regions under consideration.

Locality		Situation		Height (m)	Anual mean Temperature	Yearly Precipitation (mm)	MARTONNE's Index
		N. L.	E. L.				
1. Manchouli	(滿洲里)	49°.35′	117°.26′	650.3	−1.8	254.0	31
2. Hailar	(海拉爾)	49°.14′	119°.43′	608.6	−2.6	308.3	41
3. Pokotu	(博克圖)	48°.46′	121°.55′	694.6	−1.2	410.1	46
4. Chalantun	(札蘭屯)	48°.01′	122°.44′	315.6	2.2	468.2	38
5. Tsitsihar	(齊々哈爾)	47°.22′	123°.55′	210.0	2.9	479.8	37
6. Angangki	(昂々溪)	47°.10′	123°.49′	149.3	2.6	362.2	29
7. Anta	(安達)	46°.24′	125°.19′	147.1	2.5	427.3	34
8. Ilan	(三姓)	46°.20′	129°.33′	100.0	2.5	545.9	43
9. Harbin	(哈爾濱)	45°.45′	126°.38′	150.5	3.0	553.5	42
10. Taonan	(洮南)	45°.20′	122°.45′	150.0	4.2	392.7	27
11. Imienpo	(一面坡)	45°.04′	128°.04′	210.3	3.2	707.5	57
12. Mutankiang	(牡丹江)	44°.35′	129°.36′	241.0	2.4	528.4	42
13. Yaomen	(窰門)	44°.33′	125°.43′	178.4	4.0	520.8	37
14. Hsinking	(新京)	43°.55′	125°.18′	214.7	4.5	644.8	44
15. Chengchiatun	(鄭家屯)	43°.40′	123°.30′	115.5	5.5	464.7	29
16. Kungchuling	(公主嶺)	43°.31′	124°.48′	213.0	6.9	594.3	35
17. Tunhwa	(敦化)	43°.23′	128°.22′	498.0	3.3	716.3	53
18. Vladivostok		43°.07′	131°.54′	128.8	4.0	770.8	55
19. Yenki	(延吉)	42°.55′	129°.30′	168.0	5.3	462.6	30
20. Kaiynan	(開原)	42°.36′	124°.04′	93.0	5.9	682.9	42
21. Fengtien	(奉天)	41°.48′	123°.23′	42.9	7.1	666.6	35
22. Anshan	(鞍山)	41°.04′	122°.52′	35.7	8.5	783.9	42
23. Yingkow	(營口)	40°.40′	122°.14′	2.4	8.4	651.7	35
24. Fengcheng	(鳳凰城)	40°.26′	124°.02′	73.3	9.7	949.0	48
25. Penwafangtien	(熊岳城)	40°.13′	122°.11′	26.1	10.6	613.7	29
26. Dairen	(大連)	38°.54′	121°.38′	95.6	10.2	614.4	30
27. Ryojun	(旅順)	38°.47′	121°.16′	80.1	10.2	577.8	28
28. Siwantse	(西灣子)	40°.31′	114°.25′	116.7	6.3	345.0	21
29. Kalgan	(張家口)	40°.45′	114°.50′	85.6	7.9	344.0	19
30. Saratsi	(薩拉齊)	40°.33′	110°.32′	102.6	5.3	336.0	22
31. Linsi	(林西)	43°.32′	118.°08′	800.0	5.0	232.3	16
32. Chihfeng	(赤峯)	42°.19′	118.°51′	571.0	7.0	324.9	19
33. Weichang	(圍場)	41°.50′	117.°40′	950.0	6.0	435.8	27
34. Chengteh	(承德)	40°.52′	117.°49′	420.0	9.0	506.1	27
35. Ulan Bator	(庫倫)	47°.50′	107.°02′	1327.0	−2.2	257.0	32
36. Peking	(北京)	39°.57′	119.°25′	38.0	11.5	560.0	30
37. Nerchinskizavod		51°.19′	119.°37′	657.0	−3.7	407.0	64
38. Chita		52°.01′	113.°30′	708.0	−2.7	288.2	40
39. Khabarovsk		48°.28′	135.°04′	650.0	0.5	602.7	63
40. Nikolayevsk		53°.08′	140.°05′	35.5	−2.4	511.6	67
41. Blagoveshchensk		50°.15′	127.°38′	11.9	−0.7	497.7	53

damage resulting from snow movement will be found on some exposed slopes, but it is usually of comparatively localized occurrence.

In the Northeastern parts of the regions under consideration and Siberia

at large, the cold season is characterised by heavy snowfall, which generally increases with latitude. In northern Manchoukuo, the first snowfalls in September, the last snow patches melting in May. In North China, during the winter months, we meet with occasional snow storms but the total snowfall is usually not high. Heavier snowfalls occur in the region between Shantung and Nanking.

(5) **Hail.**—In northern North China, hail, which is mainly the result of local convectional storms, frequently occurs with serious effect on the crops.

(6) **Frost.**—Another important locality factor which affects plant distribution is frost. Intense radiation, such as that which takes place on a clear, calm night from open soil, or from soil covered only with low-growing vegetation, greatly reduces the temperature, although on windy nights in which the heavy, cold air is prevented from settling on the ground and getting constantly mixed by wind action with the warmer air, frost is much less frequent. In the northern regions this night radiation often causes "late frosts" in early summer and "early frosts" at the beginning of autumn, the former checking, and sometimes destroying, early vigorous plant growth, the latter shortening the end of the growing season and sometimes prematurely killing annual plants.

Although the deciduous species are ordinarily well protected from winter frost, they may be caught by late frosts. The conifers and broadleaved evergreens are usually hardy, but may suffer from exceptional winter frost at high elevations. Frost as a factor in competition is probably mainly effective in the seedling stages, when it may be lethal, but the relatively tender species are usually dominated by the hardier ones, which are not killed in such numbers in a severe frost year. Frost resistance is one of the chief factors in determining the northward range of woody plants. To endure frost, trees and shrubs must terminate their vegetative growth before the advent of freezing weather.(1) In this connection, the frost resistance of plants depends largely on their response to length of day, of which further under Photoperiodism.

South of these regions, the first frost comes towards the end of October and the last about the middle of April, while in the north, they come early in September and at the beginning of May, respectively. The approximate

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(1) KRAMER, P. J. and J. R. JESTER,: Further investigations of the effect of length of day on the length of growing season of woody plants. Amer. Jour. Bot., **23** (1936) 693.

length of the growing season therefore works out at from less than 100 days in the north to more than 250 days in the south. The crops and annual herbs generally have to complete their growth, bloom, and fructification within this short season (especially in the north). But the fact that the season, though short, is comparatively hot and that the hours of sunshine are long, seems to be very favourable (except for paticular short-day species) for neutral or long-day plants. A plant, therefore, so long as it is early ripening, such as spring wheats or oats, can flourish much further north than it could be expected to do, the cultivation of rice and cotton in Manchoukuo being also a good example.

(D) Humidity.

The moisture in the air is one of the chief factors influencing vegetation, since it directly affects the rate of transpiration of plants. Thus the amount of water that a plant loses frequently determines whether it can or cannot grow in a given habitat. Ordinarily, relative humidity is much more important to plants than absolute humidity, because the former is a measure of the evaporating power of the air. With a given amount of water vapour in the air, transpiration from vegetation and evaporation from the soil are hastened or retarded according as the temperature is raised or lowered. At any rate, of two regions, or two habitats with the same rainfall, the warmer is the drier. The air may become saturated with water and moisture may be precipitated out as dew even during dry weather if the night temperature is sufficiently low. Dew of this kind is known to be important in certain desert regions, such as parts of the Gobi Desert, where, during spring, it provides most of the surface moisture on which the ephemeral annuals live. During this season, there is usually a certain amount of rain, but not enough to supply the seasonal vegetation—in some years it amounts to only a fraction of a few centimeters.

As we have seen, relative humidity has a direct effect on vegetation by altering the evaporation "pull", the measurement of its variations being the measurement of one of the most important direct factors affecting vegetation. Vegetation, which also absorbs more of the radiant energy of sunlight than does most soils, keeps cool by using up heat in the process of transpiration,(1) so that by both lowering the temperature and by increasing the humidity, the greater the mass of vegetation the more the likelihood of rain.

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(1) CURTIS, O. F.: Leaf temperatures and cooling of leaves by radiation. Plant Physiol., **11** (1936) 343–364.

These reactions of vegetation and humidity can be clearly appreciated when different types of vegetation, such as forest, scrub, and grassland, are contrasted, because the denser masses, such as closed forests, tend to raise the humidity,(1) lower the surrounding temperature, and thus cause precipitations.

(1) **Humidity recorded.**—The records of humidity at meteorological stations are of little direct value in the study of individual plant communities, for not only will the value of most of these inevitably differ from that of the station, but in stratified communities the humidity of the air of the different strata will also differ. This is very obvious in the case of forest and of all closed woody vegetation, and also true of tall herbaceous vegetation.

It is thus of great importance in studying the water relations of the plants of any stratified community, to take into consideration the variations in humidity of the air of the different strata. In these circumstances, at the present time when records of this kind are lacking, we are compelled to rely on meteorological records insufficient in numbers to enable definite conclusions, although they do show that humidity, like rainfall, decreases from the southeast to the northwest, being highest during summer. The seasonal variation for the different areas should be compared with the seasonal distribution of precipitation. In the western half of Manchoukuo and North China, the yearly mean humidity is about 60% or still less, which is from 10 to 20% less than that of Japan proper. The air is very dry in November, but more so in April and May, when the humidity falls to about 50%, whereas January, February as well as July and August are months of relative high humidity, due to low temperature in the former case and to rain in the latter. And if we consider humidity with reference to locality, in the southern district dryness is fairly moderate, whereas in the northwestern region, which is a part of the great Mongolian wilderness, there is sometimes extreme dryness.

Father GHERZI, of Zikawai Observatory, Shanghai, has prepared a map showing the average ralative humidity of different regions; which is reproduced here (Fig. 5).

(E) Evaporation

The amount of evaporation, which has the closest connection with the hydrophysiology of plants, is subject, much more than humidity, to wind velocity, temperature, atmospheric pressure, and sunshine. The rate of evapo-

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(1) CURTIS, O. F.: Comparative effects of altering leaf temperatures and air humidities on vapour pressure gradients. Plant Physiol., **11** (1936) 595–603.

Fig. 5. The annual average of relative humidity in China and its adjacent regions. (after P. E. GHERZI)

ration has marked influence not only on the amount of the water lost from plants through transpiration but also in reducing the water content of the soil.

Transpiration is also affected by wind, atmospheric pressure, altitude, exposure, cover, and water content of soil. It is often so greatly increased and growth retarded to such an extent on the windward side of trees that the larger part of the exposed crown is on the leeward side.

Evaporation largely determines the benefits of rainfall, especially where

the latter is less than 500 mm annually. In a certain place, where evaporation is low, 350 mm of precipitation is sufficient to support such a growth of grasses that seems to form the boundary between the true steppe and prairie, while at another, where evaporation is high, a precipitation of 500 mm or more is required. The ratio of precipitation to evaporation (P-E Quotient)[1] therefore gives the nearest approach that is yet possible to an ideal index of the external moisture relations of plants.[2] The Desert has a lower ratio. In regions where it is between 60 and 80 to 85 per cent, we find the true prairie; where the ratio is greater than 100, i. e., where rainfall exceeds evaporation, we find continuous forests.[3]

At any rate, as with humidity, the amount of evaporation recorded at a meteorological station does not represent the total water loss in manner similar to that of plants, but the readings give one of the most useful records indicating the evaporation stress of the air as it affects the surrounding vegetation.

For these purposes the clay-cut atmometers, as devised by LIVINGSTON,[4] is recommended. It is most widely used by ecologists, since it gives more suitable value for a plant body than that from water surface. Indeed, different plants, because of differences in stomatal movement, density of cell sap, colloidal content of cells, incipient drying, etc., respond differently. The readings of the loss of water from atmometers placed at the general level of the transpiring vegetation in different habitats and various levels of the same vegetation furnish one of the most useful records for the study of micro-climate in habitats. The amount of evaporation in the northwestern part of these regions is very great compared with that of Japan proper, because of the dry air and winds which blow so constantly, and because where irrigation water is scarce, evaporation is a factor of special importance. Unfortunately, the scientific data on the subject as a whole are very limited, although the following figures taken from local records are probably not far wrong.

Evaporation is least in May and most in January, the total for a year, in

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(1) THORNTHWAITE, C. W.: The climates of North America according to a new classification. Geogr. Rev., **21** (1931) 633.

(2) LIVINGSTON, B. E., and F. SHREVE,: The distribution of vegetation in the United States, as related to climatic conditions. Carnegie Inst. Wash., Pub., (1921) 284.

(3) TANSEAU, E. N.: Forest centers of eastern America. Amer. Nat., **39** (1905) 874–889.

(4) LIVINGSTON, B. E.: Atmometers of porous porecelain and paper, their use in physiological ecology. Ecology, **16** (1935) 438–472.

North China, being from about 1300 to 1700 mm. This value, which is small during the three months of December, January, and February, begins to increase from about March. During the three months of May, June, and July, it is double that of Japan proper.

(F) Light

Light, which is one of the most important factors determining the growth of plants and the development of vegetation, promotes the germination of a large number of seeds and fruits, although it inhibits or interfers with others. It modifies the permeability of protoplasm, the absorption and use of solutes,[1] protoplasmic streaming, and antocyanin formation. Light is also the most powerful environmental factor modifying stomatal movement, which has such profound effect upon transpiration. Phototropic response is believed to be due to growth accelerating substances, light influencing both the formation and the transport of these growth regulators.

Notwithstanding these profound phenomena, from the viewpoint of ecology, it is best to say in sum, that the "light climate" of a region, so far as it affects vegetation depends on (1) its quality, (2) its intensity and total duration, and (3) its time distribution.

(1) **Light quality.**—Only about 39 per cent of the total radiation reaching the earth from the sun is visible light. Of this, about 60 per cent is infra red, and 1 per cent ultraviolet. But during winter, a higher percentage of red light and a lower one of blue light reach the earth than in summer. On cloudy days, the intensity of light is not only less than on clear days, but its quality differs widely. Because of the shorter column of atmosphere through which it passes, not only is sunlight at high altitudes more intense than at lower elevations, but it is also relatively richer in the shorter wave lengths of visible radiation and in ultraviolet. Out of the total radiant energy incident upon a leaf, about 50 per cent is transformed into heat energy and consumed in vaporizing water. Consequently, owing to the accompanying heating effect, the effect of light upon plants and vegetation, generally speaking, forms a complicated study.

The reports of the various workers mentioned on the subjects of reflection, absorption, and transmission of radiation in different parts of the spectrum

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(1) HOAGLAND, D. R.: The plant as a metabolic unit in the soil-plant system. Essays in geobotany, (1936) 219–245.

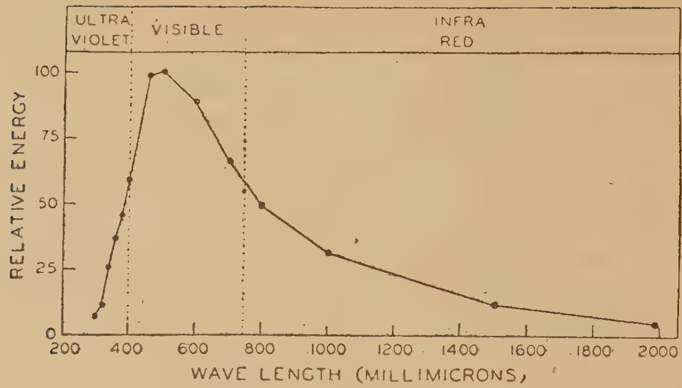

Fig. 6. Distribution of energy in the ultraviolet, visible, and infrared regions of the solar spectrum at the earth's surface. (Drawn by P. R. BURKHOLDER from data by FOWLE)

should prove of considerable value in interpreting the effect of light on photosynthesis and other physiological processes.

Light influences the number and position of the chloroplasts named chlorophyll, with the cooperation of which last, it is able to synthesize carbohydrates.(1) Any part of the radiant energy that is within the visible range of the spectrum(2) will induce photosynthesis, provided its intensity is sufficiently great; but in reality during this process only a very small amount of the energy is used.(3)

The results of HOOVER's recent investigations on the effect of different wave lengths of radiation on the rate of photosynthesis of wheat plants(4) show maximum photosynthesis at 655 mμ in the red, and a secondary maximum of 440 mμ in the blue. The green region of the spectrum is relatively less effective in photosynthesis, presumably, because of the smaller proportion of the radiation that is absorbed by leaves in this range of wave length.

The absorbed proportion incident upon a leaf is frequently around 80 per

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(1) It is from this radiant energy that chlorophyll absorbs certain wave lengths (from about 0.75 to 0.4 micron) which enable the chloroplasts to manufacture food.

(2) Although a few of the longer wave lengths of ultraviolet apparently are effective in photosynthesis, in general this process can occur only in radiation of the visible part of the spectrum.

(3) In the case of *Polygonum*, *Tropaeolum*, and *Helianthus*, it was found to be only 0.42 to 1.66 per cent of the radiant energy available for photosynthesis.

(4) HOOVER, W. H.: The dependence of carbon dioxide assimilation in a higher plant on wave length of radiation. Smithsonian Misc. Coll. 95 (1937) No. 21.

cent[1] which, however, varies with the kind of leaf and the light intensity. On the other hand, for all normally green leaves, the reflected proportion varies, maximum reflection apparently occurring in the range of the green part, largely according to wave length.[2] Moreover, transmission is relatively high in the green, relatively low in the blue-violet, short in the red, and greatest in the long red.

In general, because of the greater proportionate absorption in the red and blue parts of the spectrum, under canopies of needle-leaved trees, the change in the quality of the light is slight, but underneath canopies of broad-leaved trees, a higher percentage of green light occurs. The herbs, shrubs, and smaller trees growing in such forests receive light, which is not only much less intense than full sunlight, but also differs in quality from the light that impinges on the forest canopy.

From extensive studies on the transmission of light through isolated upper epidermises of leaves of all kinds, SCHANDERL and KAEMPFERT[3] obtained maximum values of 98 per cent with those of shade plants and minimum values of 15 to 25 per cent with those of desert plants or of plants growing at high altitudes. The latter also caused the incident radiation to become much more diffused than did the former. Colorless epidermises transmitted in about equal proportions all the wave-lengths, but those containing anthocyanin acted as filters, reducing the percentage, particularly, of blue-violet radiation. Ultra-violet radiation of wave lengths shorter than those found in sunlight has a pronounced injurious effect upon plants.[4] The effects of the sunlight ultra-violet which naturally falls upon plants are, in general, very similar to those of the blue-violet region of the visible spectrum. MEIER,[5] however, upon exposing cultures of a *Stichococcus* (a kind of green algae) found that the green region appeared to have an actual destructive effect on algal cells, which effect probably extends to plant cells, generally. The presence of

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(1) SEYBOLT, A.: Über die optische Eigenschaften der Laubblätter. I, II. Planta, **16** (1932) 195–226, 479–508.

(2) SHULL, C. A.: A spectrophotometric study of reflection of light from leaf surfaces. Bot. Gaz. **87** (1929) 583–607.

(3) SCHANDERL, H. and W. KAEMPFERT,: Über die Strahlungsdurchlässigkeit von Blättern und Blattgeweben. Planta, **18** (1933) 700–750.

(4) POPP, H. W. and F. BROWN,: The effect of ultraviolet radiation upon seed plants. In biological effect of radiation, B. M. DUGGAR, editor. **II** (1936) 853–887.

(5) MEIER, F. E.: Growth of a green alga in isolated wave length regions. Smithsonian Misc. Coll. **94** (1936) No. 17.

flavone and anthocyanin in alpine plants has been ascribed to the action of intense light, particularly of the shorter wave lengths.[1]

All experiments on the effect of limited ranges of wave lengths of light led to the general conclusion that the full spectrum of sunlight is more satisfactory for the development of plants than any portion of it.[2, 3] Wave-lengths shorter than 5290 Å were eliminated, the most marked differences occurring in fresh weight, dry weight, and composition.[4] A considerable decrease in the amount of starch and total carbohydrates and an increase in the amount of total nitrogen were noted in most plants,[5] those allowed to develop in a blue-violet light usually being similar in gross morphology to those allowed to develop in a full spectrum, although they are often smaller and more compact. But the blue-violet end of the spectrum proves to be somewhat more efficient on the basis of dry weight than the red end. As a rule, plants grown under the longer wave lengths of the visible spectrum somewhat closely resemble etiolated plants.[6]

(2) **Light intensity and total duration** (Tolerance). — The intensity of light varies throughout the day and year, being greatest when the sun is at zenith, when the angle that it makes with the surface of the earth is greatest, and lowest when this angle is least. Since the effect of angle upon light intensity is due to the absorption of light waves by the atmosphere, the daily maximum occurs at noon sun time and the yearly one at the beginning of summer. Among the most important factors causing variations from time to

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(1) SHIBATA, K.: Untersuchungen über das Vorkommen und die physiologische Bedeutung der Flavonderivate in den Pflanzen. I. Bot. Mag. (Tokyo), **29** (1915) 118–132.

——, und M. KISHIDA,: Idid. II. Ein Beitrag zur chemische Biologie der alpine Gewächse. Ibid., **29** (1915) 301–308; 316–332.

——, und I. NAGAI,: Ibid. III. Über den Flavongehalt der Tropenpflanzen. Ibid., **30** (1916) 149–178.

(2) POPP, H. W.: A physiological study of the effect of light of various ranges of wave-length of the growth of plants. Amer. Jour. Bot., **13** (1926) 706–736.

(3) MONTFORT, C.: Studien zur vergleichenden Oekologie der Assimilation. Jahrb. Wiss. Bot., **71** (1929) 52–105; 106–148.

(4) SHIRLEY, H. L.: The influence of light intensity and light quality upon the growth of plants. Amer. Jour. Bot., **16** (1929) 354–390.

(5) ARTHUR, J. M., J. D. GUTHRIE, and J. M. NEWELL,: Some effects of artificial climates on the growth and chemical composition of plants. Ibid., **17** (1930) 416–482.

(6) POPP, H. W. and F. BROWN,: Effects of different regions of the visible spectrum upon seed plants. In biological effects of radiation, B. M. DUGGAR, editor. **II** (1936) 763–790.

time are the humidity of the atmosphere and the amount of cloudy weather. The total radiation received on a cloudy day may be as low as 4 per cent of that during the same season and station on a day of full sunshine.(1) In northern latitudes, such as the Okhotsk Region, where rainfall is abundant but the temperature too low for wealthy development of vegetation, amount of sunshine is a very important climatic factor.

The total duration of the continuous available light varies, obviously, with the latitude. In intermediate latitudes, the total duration and time distribution of the effective light are affected both by the length of day and by the actual length of the growing season. The intensity of illumination is naturally also affected by the height of the sun in the sky. With a clear sky, only the lack of sufficient light intensity at sunrise or sunset acts as a limiting factor to photosynthesis. In general, with increase in light intensity we have increase in the rate of photosynthesis until some other limiting factor asserts itself. At relatively low light intensities, so long as carbon dioxide is not the limiting factor, the rate of photosythesis is approximately proportional to the light intensity received up to about 20 per cent of full summer sunlight. With higher intensities, the shape of the curve becomes steeper after reaching its peak, shade-plants showing a decrease at lower intensities than sun-plants.(2) The effect of various light intensities on the rate of photosynthesis of wheat plants exposed to different atmospheric concentrations of carbon dioxide is shown graphically in Fig. 7.(3) These results are obtained only when a single leaf or a small plant, all parts of which are well illuminated, is used as experimental material. If, however, the effect of light is considered in terms of an entire plant, light is not usually a limiting factor in photosynthesis, however exposed it may be to full sunlight. This is no doubted due to the fact that many of the inside leaves on the plant are heavily shaded, so that ecologically, the total photosynthesis on a large tree may well be thought to increase progressively with increased illumination up to the maximum possible sunlight intensity. Of course these specialities must be recognized that some species will thrive and photosynthesize satisfactorily only in fully exposed locations, while others are able to complete their normal life cycles in deeply

(1) SHIRLEY, H. L.: Light sources and light measurements. Plant Physiol., 6 (1931) 447–466.

(2) ——: The effect of light intensity upon seed plants. In biological effects of radiation, B. M. DUGGAR, editor. II (1936) 727–762.

(3) HOOVER, W. H., E. S. JOHNSTON and F. S. BRACKETT,: Carbon dioxide assimilation in a higher plant. Smithsonian Misc. Coll., 87 (1933) No. 16.

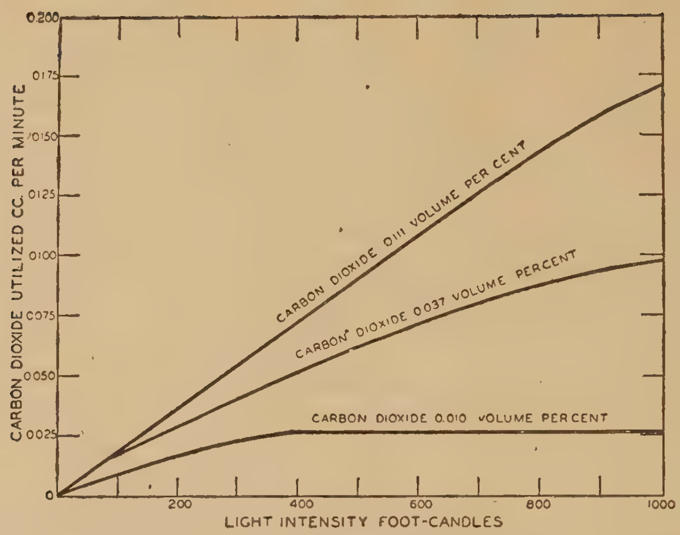

Fig. 7. Relation between different light intensities and rate of photosynthesis of wheat plants at three different carbon dioxide concentration. (after W. H. HOOVER, et al)

shaded habitats. Above an understorey of young trees and shrubs growing in a forest with a closed canopy, the light is often about 20 per cent, whereas below the understorey it is only from about 1 to 5 per cent.(1) Light reaches the forest floor by filtering through or between the crowns of trees or by reflection from the leaves and twigs. The amount of light passing unabsorbed through leaves is small, from 0.03 to 0.6 per cent for sun-leaves and 0.3 to 2 per cent for shade-leaves. Intense light is associated nearly always with dry habitats and high transpiration. The mean correlation coefficient of transpiration with radiation of a wide variety of *Leguminocea* is 0.48, and for a similar lot of crops belonging to *Graminea* 0.65. At night, the water loss by transpiration amounts from only 3 to 5 per cent of that lost during the daytime.(2, 3)

When the sun-leaves were in the sun and the shade-leaves in the shade,

(1) SHIRLEY, H. L.: Light as an ecological factor and its measurement. Bot. Rev., 1 (1935) 355–381.

(2) BRIGGS, L. J. and H. L. SHANTZ,: Hourly transpiration rate on clear days as determined by cyclic environmental factors. Jour. Agric. Res., 5 (1916) 583–650.

(3) The influence of the duration of the daily light period is shown in another manner which will be mentioned again in later paragraph entitled "Photoperiodism".

the former transpired from about three to six times that of the shade-leaves, but with both in the sun or both in the shade, the sun-leaves transpired only from one to two times that of the shade-leaves per unit of surface.

Local conditions, especially those caused by land relief, affect the incidence of light, and this often corresponds with the sharply differentiated types of vegetation within a small area, although in many cases the observed differences probably depend upon disparities in temperature and water relations of soil and air.

In general, absolute dry weight, percentage of dry matter in the tops, rigidity of stem, and leaf thickness, all these increased with increase in the intensity of light up to full sunlight, provided other factors were not limiting the growth. Maximum height of plants and maximum leaf area were attained, although light intensities brought about considerable delay in the time of maximum flowering and fruiting. But, usually, every phase in the growth of typical shade-species is retarded by high light intensities.[1, 2]

A number of weeds were found to grow best in about two-thirds full light, while cultivated crops produced maximum dry weight under full light, showing marked decrease when shaded,[3] whence it seems to be true that rate of growth usually increases with increased light intensity up to 50 (for shade-plants) or even 100 per cent (for sun-plants).

Total absence of light results in greatly attenuated, weak stems, with tissues weakly differentiated, and little mechanical tissue. Due to lack of chlorophyll, a plant, which is pale yellowish or whitish, is said to be etiolated. The characteristic elongation of stems with darkness appears to result mostly from considerable increase in the length of the component cells.[4] Etiolated plants illuminated only from 2 to 10 minutes daily showed profound changes in their form and structure. Thus the structures of plants are closely related to their light relations. It is therefore thought that hairs, resins, or waxes on an epidermis may serve more to reduce the intensity of the incident energy than to check loss of water by transpiration.[5]

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(1) POPP, H. W.: Effect of light intensity on growth of soy beans and its relation to the autocatalyst theory of growth. Bot. Gaz. 82 (1926) 306–319.

(2) SHIRLEY, H. L.: The effects of light intensity upon plants. In biological effects of radiation, B. M. DUGGAR, editor. **II** (1936) 727–762.

(3) ZILLICH, R.: Über der Lichtgenusz einiger Unkräuter und Kulturpflanzen. Fortsch. Landw., **1** (1926) 461–470.

(4) CLEMENTS, F. E. and L. L. FRANCES,: Factors in elongation and expansion under reduced light intensity. Plant Physiol., **9** (1934) 767–781.

(5) POPP, H. W. and F. BROWN,: Effects of different regions of the visible spectrum upon seed plants. In biological effects of radiation, B. M. DUGGAR, editor. **II** (1936) 786–790.

Instead of the ecological designations hygrophyte, mesophyte, and xerophyte, which are based on water relations, a classification based on light relations, namely, polyactinophyte, mesoactinophyte, and oligoactinophyte, is suggested.

In open woodland, where much light filters through the leaves and branches and where there is an adequate supply of water, layers of shrubs, tall herbs, low herbs, and ground layers of mosses, lichens, liverworts, and fungi are usually more or less developed. At such places, the light intensity under a tree with a rather open crown is generally only from one-tenth to one-twentieth that of full sunlight. But where the crowns of the trees grow close together, such as in the medial or climax stages of deciduous forests, some of the layers, because of the diminished light, are frequently nothing but low herbs, the ground layers disappearing. Since an understorey of shrubs, with the light reduced to less than 5 per cent, effectively excludes seedlings of coniferous trees,[1, 2] in the natural development of forests through the various successional stages, light is usually a controlling factor, although other factors, such as water content of the soil, may also be critical for the success or failure of the tree seedlings. That is, the real shade-plant not only can grow under low light intensities but also exist for a long period under conditions unfavourable for photosynthesis. Trees may be grouped according to their ability to carry on photosynthesis and grow in decreased light intensities.[3] It may be noted, for example, in the development of a deciduous forest, that the species characteristic of the climax stages of succession are more or less tolerant.

Empirical scales of tolerance may be prepared by studying such characters as density of crown, self-pruning, relative height growth, and the growth of the young stand under the old.

A study of the growth of young trees under the parent trees throws much light on their ability to endure shade. The most direct method of determining the tolerance of forest trees is to measure the light intensity under various forest canopies where the seedlings are growing or fail to grow.

Undoubtedly, development of undergrowth of shrubs, herbs, mosses, etc.,

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(1) SHIRLEY, H. L.: Light intensity in relation to plant growth in a virgin Norway pine forest. Jour. Agric. Res., **44** (1932) 227–244.

(2) HIRAO, T.: Some observation on the reaction of *Larix Gmelini* var. *coreana* seedlings to shade (Japanese). Jour. Jap. For. Soc., **20** (1938) 51–56.

(3) TOUMEY, J. W.: Foundations of silviculture upon an ecological basis. **1** (1928) 60.

on the forest floor is often largely affected not only by the amount of light received but also by competition for water and nutrient.[1]

The leaves of intolerant trees cannot photosynthesize under weak, diffused light. In fact, intolerant trees, needless to say, clear themselves of the lower leaves and branches, in the forest, even when they grow as isolated individuals, so that in the forest, the tree grows slender and straight, its height being very great relative to its diameter. Tolerant species, such as *Thuja* or *Taxus*, retain their branches, and the stem is thick in proportion to its height.

The minimum light at which photosynthesis occurs in *Pinus ponderosa* has been found to be 17 per cent, but only 1.9 per cent is required for the very tolerant *Acer saccharum*. BATES and ROESER[2] studied the effects of low light intensities on the growth of a number of species of evergreens, native to the western United States. Their results show that *Sequoia sempervirens* seedlings were able to maintain their initial dry weight in a light intensity less than 1 per cent of full sunlight, *Pinus edulis* required about 5 per cent, while the other three species (*Pinus ponderosa, Picea Engelmanni*, and *P. taxifolia*) were intermediate in their requirements.

Thus trees in the regions under consideration may be also grouped according to their ability to carry on photosynthesis and grow in decreased light intensities, i. e., according to their tolarance. The following sequence, however, is not absolute.

List of Tolerance

Broad-leaved trees.

Very tolerant: *Acer ukurunduense* TRAUTV. et MEY., *A. pseudo-Sieboldianum* KOM., *A. tegmentosum* MAX., *A. barbinerve* MAX., etc.

Tolerant: *Tilia amurensis* RUPR., *Acer mandshuricum* MAX., *Prunus Padus* L., *Ulmus laciniata* MAYR, *Tilia mandshurica* RUPR. et MAX., *Populus Maximowiczii* A. HENRY, *Syringa amurensis* RUPR., *Cornus alba* L., etc.

Medium: *Quercus acutissima* var. *septentrionalis* LIOU, *Fraxinus mandshurica* RUPR., *Phellodendron amurense* RUPR., *Prunus Maackii* RUPR., *Acer mono* MAX., *Betula davurica* PALL., *Kalopanax pictum* NAKAI, *Maakia amurensis* RUPR. et MAX., etc.

Intolerant: *Alnus sibirica* FISCH. ex TURCZ., *Juglans mandshurica* MAX., *Populus*

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(1) PEARSON, G. A.: Light and moisture in forestry. Ecology, **11** (1930) 145–160.

(2) BATES, C. G. and J. ROESER,: Light intensities required for growth of coniferous seedlings. Amer. Jour. Bot., **15** (1928) 185–194.

Simonii CARR., *Ulmus propinqua* var. *suberosa* MIYABE, *Betula costata* TRAUTV., *Populus Davidiana* DODE, *Salix Matsudana* KOIDZ., *Zizyphus jujupa* var. *incrmis* REHD., etc.

Very intolerant: *Betula platyphylla* SUKAT., *B. platyphylla* subsp. *mandshurica* KITAG., *B. Ermanii* CHAM., *Quercus mongolica* FISCH. ex TURCZ., *Ulmus pumila* L., *Prunus Davidiana* FRANCH., *Crataegus sanguinea* PALL., *Zizyphus jujupa* MILL., *Salix Kochiana* TRAUTV., *S. mongolica* SIUZEV, etc.

Coniferous trees.

Very tolerant: *Taxus cuspidata* SIEB. et ZUCC., *Abies nephrolepis* MAX., *Picea koraiensis* NAKAI, etc.

Tolerant: *Abies holophylla* MAX., *Picea jesoensis* CARR., *P. Mastersii* MAYR, *P. Meyeri* REHD. et WILS., *P. obovata* LEDEB., *Thuya koraiensis* NAKAI, *Juniperus rigida* SIEB, et ZUCC., etc.

Medium: *Pinus koraiensis* SIEB. et ZUCC., *P. bungeana* ZUCC., etc.

Intolerant: *Pinus Tokunagai* NAKAI, *Biota orientalis* ENDL., *Larix Gmelini* LEDEB. ex GORD., etc.

Very intolerant: *Larix Principis-Rupprechtii* MAYR, *L. olgensis* A. HENRY, *Pinus densiflora* SIEB. ex ZUCC., *P. sylvestris* L., *P. tabulaeformis* CARR., *P. pumila* REGEL, etc.

(3) **Time distribution of light** (Photoperiodism). — A knowledge of photoperiodism should be helpful in the task of extending the northern or southern range of various plants. It is established that, in general, a definite relationship exists between response of a given form to day length and its origin with reference to latitude. At 49° N latitude, for example, on the shortest day (December 21) the sun shines for only about 8.2 hours; on the longest (June 21) for about 16.2 hours. At 25° N on the shortest day the sunshine lasts about 10.6 hours, on the longest about 13.7 hours. At higher latitudes, the annual variation in day-length is greater, at lower latitudes less. A prolonged period of daily light, such as occurs in higher latitudes in summer, incites some plants to more vigorous and prolonged vegetative growth, flowering and fruiting being delayed until the short autumn days arrive. On the other hand, some plants respond in exactly opposite manner, requiring a prolonged daily light period for flowering and fruiting. Generally speaking, tropical and subtropical plants, being adapted to a short day normally develop within a day length range of from about 10 to 14 hours, arctic species growing above a latitude of about 60° being adapted to very long days. In the temperate zone many of the early spring or late summer blooming wild flowers are

short-day plants, while a large number of late spring and early summer blooming wild flowers are long-day plants. Since these two extremes show every intermediate stage, among the species of the same temperate zone many "indeterminate" plants that may be adapted to a relatively wide range in day length are also recognized.(1)

T. EGUCHI considered, however, that there are two different stages in the course of flower formation, namely the differentiation of flower bud and the subsequent development of differentiated bud to flowering, and that these stages would receive the effects of day-lengh independently. To make clear this relationship, using sixteen kinds of plants, he carried out various experiments.(2)

The critical light period for flowering may be altered to a certain degree by temperature, while, conversely, the favourable temperature range for flowering may be shifted by the effect of day length.(3, 4) Since, at any rate, periods of daily illumination within certain definite limits are essential to the flowering of particular species, the daily light periods also determine the type of vegetation growth. Obviously, plants that require a long day (more than 14 hours) to flower and fruit, for example, cannot live in the tropical zone even though increase in altitude may provide the necessary temperatures. If a plant that requires a short-day of less than 12 hours to blossom, were to migrate still farther north from a latitude of about 48° N, it might not be able to blossom at all because of the excessive length of day during the growing season,(5) or the seeds might freeze before maturing. Wheat, oats, barley, rye, spinach, beets, radish, lettuce, timothy clover, hibiscus, etc. show these characteristics, being accustomed to longer days, while rice, Indian corn, soy-bean, cosmos, salvia, coleus, asters, dahlia, poinsettia, chrysanthemum, nasturtium, violets, etc. are accustomed to shorter days. Some of the better known examples of plants indeterminate in these respects are the sunflower, dandelion, chickweed, tomato, cotton, buckweat, etc.(6)

(1) RASUMOV, V. J.: Über die photoperiodische Nachwirkung in Zusammenhang mit der Wirkung vershiedener Aussaattermine auf die Pflanzen. Planta, **10** (1930) 345–373.

(2) EGUCHI, T.: Studies on the photoperiodic responses of plants before and after the differentiation of flower bud. Bull. Chiba Coll. Horti. **4** (1939).

(3) STEINBAUER, G. P.: Dormancy and germination of *Fraxinus* seeds. Plant Physiol., **12** (1937) 813–824.

(4) ROBERTS, H. H. and B. E. STRUCKMEYER,: The effect of temperature upon the responses of plants to photoperiod. Science, 85 (1937) 290.

(5) ALLARD, H. A.: Length of day in relation to the natural and artificial distribution of plants. Ecology, **13** (1932) 221–234.

(6) MEYER, B. S. and D. B. ANDERSON,: Plant physiology, 599–607.

In experiments with woody species, MOCHKOV(1) found that in the natural full day, *Salix lanata* L., a representative of high latitudes, ceased growth long before winter set in, while *Robinia pseudo-acacia* L., from lower latitudes, did not stop growth until the branches were killed by frost. It is concluded that frost resistance, one of the chief factors determining the northward range of woody plants, depends to a considerable extent of response of these plants to length of day. To successfully withstand the winter they must terminate their vegetative activity under normal full day conditions before the onset of cold, as already mentioned in the preceding section.

In tests made by GARNER and ALLARD(2, 3) cultures of *Liriodendron tulipifera* were transferred to the greenhouse in September, one of the series receiving weak supplementary illumination from sunset till midnight. In the same way, ODEN, by lengthening the autumn day to 17 hours, caused the usual rapid autumn leaf fall in *Acer campestre, Lonicera periclymenum*, and *Viburnum opulus* to be replaced by continuous dropping of the leaves. After normal leaf-fall, added illumination caused new buds to unfold and new leaves to develop. Similar phenomena were witnessed with street-trees, such as *Platanus, Acer*, etc., planted close to street lamps (cf Fig. 8).

Thus, any comprehensive study of the factors affecting the distribution of plants should take account of the length of day as well as the usual temperature, water content, and light intensity, for which purpose, it would be best to analyse at first the complete developmental period of the plant, dividing it into three phases,(4) (a) from planting to appearance of the young shoots, (b) from appearance of the shoots to the flowering or earing stage, (c) from flowering or earing to ripening of the seed. The duration of the first phase depends on various enviromental conditions, including those of a purely local, accidental character, the chief factors being temperature and rainfall. As regards duration of the second phase in relation to geographical location, all the plants tested fell into three groups, (i) those in which the time required for

(1) MOCHKOV, B. S.: To the question of photoperiodism of certain woody species. Bull. Appl. Bot., **23** (1929–1930) 509–510.

(2) GARNER, W. W. and H. A. ALLARD,: Effect of the relative length of day and night and other factors of the environment of growth and reproduction in plants. Jour. Agric. Res., **18** (1920) 553–606.

(3) —— and ——: Further studies in photoperiodism. The response of the plant to relative length of day and night. Ibid., **23** (1923) 871–920.

(4) KUZNETZOVA, E. S.: Geographical variation of the vegetation period in cultivated plants. Bull. Appl. Bot., **21** (1928–1929) 321–446.

Fig. 8. Delayed leaf-fall of *Platanus* trees, planted close to street lamps (face P. 470). (M. TAKAHASI)

Fig. 9. The uprooting of *Larix Gmelini* LEDEB. et GORD. in the northern Khingan Mountains where the soil has permanently frozen (face P. 473). (M. TAKAHASI)

Fig. 10. *Equisetum hyemale* L. and *Dryopteris crassirhizom* NAKAI (indicators of deep shade) are seen under the deciduous forest (face P. 477). .
(M. TAKAHASI)

Fig. 11. *Artemisia brachyloba* FRANCH. (indicator of full light) are growing on sunny gravelly slopes (face P. 477).
(M. TAKAHASI)

completion of this phase of development decreases with increase in geographical latitude (long-day plants), (ii) those in which the duration of this phase decreases with decrease in latitude (short-day plants), and (iii) those which are affected only slightly by geographical factors (indeterminate or neutral plants). At the same latitude and with simultaneous planting, the duration of the second phase is regulated chiefly by temperature. With equal temperature the duration of the second phase of development in different latitudes and in the same latitude but at different altitudes is determined by the number of hours of sunlight during the day. Other factors, such as humidity, cloudiness, and soil fertilization, either play only a minor role in such important phases of development as earing or flowering, or they are of an accidental character.

As to the third phase of development, all plants behave in almost the same way, the rate of development increasing with decrease in latitude and also with decrease in altitude. The degree of response, however, differs with the variety. The chief factors influencing geographical variation in the length of the third phase of development are temperature, rainfall, and relative humidity. In contrast with its outstanding importance in the second phase, light has no perceptible direct effect on the third phase of development.

(G) Wind

Wind affects vegetation in different ways, namely, (1) by direct or mechanical effects and, (2) by indirect or drying effects.

(1) **Direct effects.**—The actual pressure exerted by the wind depends upon the character and area of the ground surface as well as upon the density of the air. At sea level, wind with a velocity of 4.5 m per second exerts a pressure of approximately 1.6 kg per sq. m, at 13.5 m, this increases to about 12 kg, whereas at a velocity of 27 m it exerts a pressure of over 43.2 kg per sq. m.[1] With this pressure or strength the wind mechanically uproots trees or breaks off their branches or twigs, or it may permanently bend the plants, particularly on wind-swept coasts and high mountains. In the case of uprooting by wind, trees with comparatively shallow root systems, such as the *Coniferales*, are most easily injured, particularly in regions where the soil has permanently frozen or it has gravelly underlayers at certain depths (cf Fig. 9).

Together with the friction of the soil surface and the presence of masses of vegetation, the velocity and, consequently, the pressure exerted by the wind

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(1) SMITH, J. W.: Agricultural meteorology. New York, (1920).

rapidly increased with height. This explains the greater velocity attained on exposed seacoasts and at higher altitudes that are free from the obstructions caused by masses of vegetation.

During winter and the spring months, most areas consisting of soils derived from loess are affected by wind erosion. It is the general opinion that all the loess of North China was originally eroded by wind from the desert regions or river flood plains during the Diluvial age.

The ability of the wind to transport is extraordinary, especially when it accompanies a small cyclone as it so often does. The dust may be so dense as to veil the sunshine for some hours, necessitating lamps even at midday. Dustladen wind, sand, snow, and hail also have erosive effect on vegetation, sometimes to the extent of wearing away the bark of trees or shrubs in wind-swept areas. Although, as a matter of fact, the wind is an important agent for conveying pollens and spreading seeds, transportation of moisture and fertile soil, usually brings about low temperature, removes moisture, and damages buds, blossoms, and fruits.

(2) **Indirect effects.**—The drying effect of winter winds, particularly in late winter when the air is warm but the soill still frozen, often results in winterkilling of many trees, shrubs, winter wheat, etc. Even a wind velocity of 0.9 m per second, when it occurred intermittently at intervals of several hours, increased the transpiration rate 20 to 30 per cent in *Helianthus annuus.*(1) A gentle breeze is relatively much more effective (not absolute amount) in increasing the transpiration rate than winds of great velocity. Winds of very high velocity have been observed to retard transpiration. This is probably the result of closure of the stomata under such conditions.

Since the velocity of the wind increases with the height above the soil surface, trees especially suffer from the drying and the mechanical effects. Low-growing vegetations, such as rosette and mat forms, are much less affected. Transpiration is often so increased and growth so retarded on the windward side of trees that the larger part of the exposed crown is on the leeward side. The height to which many plants can attain is limitted by their ability to absorb and transport water upward rapidly enough to replace that lost through transpiration. On wind-swept coasts and on high mountains, excessive water loss results in stunted and guard growths. A reasonable con-

(1) MARTIN, E. V. and F. E. CLEMENTS,: Studies of the effect of artificial wind on growth and transpiration in *Helianthus annuus.* Plant Physiol., **10** (1935) 613–636.

clusion from this is that the chief value of protective coverings at tender growing points, such as the scales of buds, is to keep them from drying up, although protection from freezing is also conceivable.

(3) **Wind recorded.**—The cold dry winds of North China and Mongolia in winter are caused by anticyclones over the interior of Asia, but winds detrimental to land life are chiefly typhoons, which come inland from the sea. All these elements have already been referred to in the preceding section.

From the viewpoint of ecology, we must consider not only typhoons, but also strong winds generally, especially their direction, velocity, and frequency.

In North China and southern Manchoukuo, the wind, during the three summer months, blows from the southwest, south, or east, whereas from winter to the following spring, the direction of origin alternates between north and southeast. In Mongolia, it blows from the northwest or north almost all the year round, the annual mean of its velocity being 4–7 m/sec. During February, March, April, and May strong northerly or northwesterly winds exceeding 10 m/sec. not infrequently blow continuously day after day, as the result of which sand and dust are blown skyward, presenting in reality the oft-heard Chinese phrase "a cloud of dust".

Since, blowing of soil often reaches its maximum in sands where destructive "blowouts" occur, a strong wind from the southwest usually stirs up the sandy decomposed soil throughout the interior of the continent, resulting in numbers of dunes all over Mongolia, crops, villages, and even forests being covered sometimes by dunes. As to the nature of these dunes, they will be dealt with in greater detail under "Aeolian Sand". The sandy soil moreover contains sodium salts (of which further later) through the scattering of which the land becomes more sterile every year with ever increasing ill consequences. Often the dunes can be brought under control by planting on them trees, such as *Salix Kochiana* TRAUTV., *S. mongolica* SIUZEV, *Populus Simonii* CARR., or *Ulmus pumila* L. This is accomplished fairly easily in North China and western Manchoukuo, but less so in the dryer parts of Mongolia. No remedy seems as yet to have been found for this serious state of affairs.

(H) Climatic indicators

Every plant is more or less a measure of environment under which it grows.(1) The impress of temperature should be most pronounced in climates

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(1) CLEMENTS, F. E.: Plant indicators. (1920).

in which it is so extreme as to be a limiting factor. The dwarf shrubs and perenial herbs in the alpine or arctic region (the dwarfing of trees at the timber line also) have long been regarded as responses to short seasons and low temperatures. But in the case of some alpine plants, at least, it is certain that dwarfing is due as much or more to water than to temperature.(1) The non-availability of the water-content is caused by the freezing or drying effects of wind. Thus dwarfing might well be regarded as due to these three factors, so that these phenomena constitute the corresponding indications. In special cases, the absence of certain life-forms and species, as a consequence of frost, for example, also plays the part of a sort of indicator. But the dominant species are usually the most important indicators for the present climate or other factors, since they usually receive the full impact of the habitat year after year. Thus, although plant communities are more reliable as indicators than individual plants, in a special case of change, such as that following a clearing or a fire, is so complete that a single relict individual furnishes information of great value regarding the original climax conditions.

It is well known that all Forest Formations, as will be seen from a later paragraph, indicate as many corresponding forest climates, for example, three main Temperate Forest Formations indicate climates with a progressive increase of rainfall usually from Warm-temperate evergreen Forest to Cold-temperate needle-leaved Forest Formation, though occasionally Temperate summer-green Forest Formation has the highest rainfall of all. In similar fashion these three Formations, coast, montane, and subalpine forests, indicate a progressive decrease in the length of season and in the temperature values.

The Associations sometimes serve to indicate still finer climatic conditions. This is well exemplified by the montane forests, in which *Quercus mongolica* — Association indicates drier and warmer climatic conditions than *Betula platyphylla — Populus Davidiana* — Association; and, similarly, *Pinus tabulaeformis* — Association than *Pinus koraiensis* — Association, but these are often obscured by edaphic indications of greater importance. The significance of light indicators is also complicated by the influence of other factors, especially of water. But light is usually the controlling factor in tolerance, as already mentioned, wherever the cannopy is closed and that water plays a decisive part only when the light intensity is higher and evaporation and competition consequently greater. At any rate, the "List of Tolerance" (cf P. 467) is an

(1) CLEMENTS, F. E.: Causes of alpine dwarfing. Science, (1907).

indirect recognition of indicator values of the respective trees. In many cases, moreover, seedlings of a particular dominant, or of all the related, are absent from the forest floor. Thus the differences between the resembling forests may be represented only by undergrowth or certain elements of it. In such cases, the subdominant shrubs and herbs must be resorted to as indicators, often, the latter, in particular, being more sensitive than the trees themselves.

Indicators of deep shade: *Adiantum pedatum* THUNB., *Dryopteris crassirhizom* NAKAI, *Equisetum hyemale* L. (cf Fig. 10), *Lycopodium clavatum* L., *L. serratum* THUNB., *Parietaria micrantha* LEDERB., *Maianthemum bifolium* F. W. SCHMIDT, *Trientalis europaea* L., *Polygonatum japonicum* MORR et DECAISNE, *P. involucratum* MAX., *Oxalis acetosella L.*, *Panax Ginseng* MEYER, *Chrysosplenium alternifolium* L., *Ch. flagelliferum* FR. SCHMIDT, etc.

Indicators of medium shade: *Dennstaedtia hirsuta* METT. ex MIQ., *Gymnocarpium Dryopteris* NEWMAN, *Polystichum craspedosorum* DIELS, *Equisetum sylvaticum* L., *Carex lanceolata* BOOTT ex GRAY, *C. siderosticta* HANCE, *Laportea bulbifera* WEDD., *Urtica cannabina* L., *Rosa davurica* PALL., *Cornus alba L.*, *Primula Maximowiczi* REGEL, etc.

Indicators of full light: *Aneurolepidium chinense* KITAG., *Aristida adscenscionis* L., *Miscanthus sinensis* ANDERS., *Delphinium grandiflorum* L., *Paeonia albiflora* PALL., *Pulsatilla chinensis* REGEL, *Papaver nudicaule L.*, *Lysimachia barystachys* BUNGE, *Scabiosa comosa* FISH. ex ROEM. & SCHULT., *Hemistepta lyrata* BUNGE, *Taraxacum sinicum* KITAG., *Convolvulus chinensis* KER-GAWLER, *Artemisia brachyloba* FRANCH. (cf Fig. 11), etc.

Thus, while certain species, or plant communities, indicate present climatic conditions, others are of great value in indicating past climate.[1, 2] For example, they outstand as indicator of climatic cycles, and whence may prove of great value in determining the proper procedure in cultivation for arid and semi-arid regions. Trees and shrubs, by virtue of their annual record of growth in rings, are the best indicators of minor climatic cycles. It has been also found that the height-growth and reproduction of dominant species of grasses, such as *Aneurolepidium chinensis*, *Stipa baicalensis* and *Artemisia pectinata*,

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(1) CLEMENTS, F. E.: The relict method in dynamic ecology. Jour. Ecol., 22 (1934) 39–68.

(2) HOYANAGI, M.: Tree-ring analysis and climatic change. Geogr. Rev., Japan, 16 (1940) 801–817.

closely correspond with rainfall of the dry and wet period. In this connection, more striking variation in the yield of crops are shown for similar periods. These subjects will be discussed further under "Indicators of productive arts".

II. Edaphic Factors

Next to climate, the most important factors determining vegetation are the edaphic ones, that is, those which depend directly on the soil in which the plants are rooted, namely, physical and chemical constitutions, water content, aeration, and temperature. Although their immediate action on vegetation is clearly distinct from that of the climatic factors, yet the nature of soils and, consequently, their different actions on plants are to a certain degree determined by the climate in which they are developed. But in studying these edaphic factors, it should be remembered at the outset that opinions regarding the definition of the soil itself differ among the various investigators, whether pedologist, geologist, ecologist, or agriculturist. For example A. G. TANSLEY and T. F. CHIPP say about the soil as follows:—(1)

In a general way, the term "soil" is applied to the layers inhabited by the root systems of the vegetation, and where this includes plants rooting at different depths, there are often various soil strata of very different nature, containing the root systems of different constituents of the vegetation.

WAHNSCHAFFE, MITSCHERLICH, and HILGARD have almost the same opinions.

J. E. WEAVER, and F. E. CLEMENTS have the following ideas:—(2)

The soil is the unconsolidated outer layer of the earth's crust, ranging in thickness from a mere film to somewhat more than 10 feet, which through process of weathering and the incorporation of organic matters has become adapted to the growth of plants. It is underlaid usually by unconsolidated parent materials into which the deeper roots of plants frequently extend.

Accoding to J. THORP:—(3)

Theoretically a soil material is not to be considered a soil until it begins to develop horizons or developmental layers in its cross section. The environmental factors which influence soil development are numerous and, when they combine to act upon different types of soil materials, the resulting variations in soils are "as numerous as the sand of the sea".

DOKUCHAEV, MWRITES, JOFFE, and JARILOW have given similar definitions.

J. LOSSING BUCK writes—:(4)

Briefly speaking, soils are the products of weathering of various kinds of rocks and

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(1) TANSLEY, A. G. and T. F. CHIPP: Aims and methods in the study of vegetation. (1926) 114–115.

(2) WEAVER, J. E. and F. E. CLEMENTS,: Plant Ecology. (1938) 173.

(3) THORP, J.: Geography of the Soils of China. (1936) 81.

(4) BUCK, J. L.: Land utilization in China. (1937) 130.

unconsolidated mineral soil materials, incorporated with more or less organic matter and showing varying degree of profile development.

With certain differences, the writer's ideas almost agree with those of BUCK. Owing to the profiles, he considers two kinds of soils, developed and undeveloped. The former agrees with the soil as defined by THORP, but the latter corresponds to his "soil materials", so to speak. The writer's soil materials are the fundamental materials of any kind of soil, developed or undeveloped, that is, a mixture of mineral colloids, clays and coarser minerals, rock fragments, and organic matter and the their decomposed substances. Geological formations, through mechanical disintegration and chemical weathering, produce most of these soil materials. More than 90 per cent by weight of ordinary air-dried soil consists of rock fragments and the inderived substances.

From the ecological point of view, soil is the outer layer of the earth's crust, inhabited by the root systems of nearly all higher plants, except parasites and epiphytes. Even floating water plants secure the necessary soluble salts that have been disolved from the soil. When soils are young, i. e., recently derived from rock or built up by deposit due to wind or water, as also badly eroded soils, they do not show a profile similar to that of mature soils upon which climate and vegetation have acted and reacted for long periods of time.

Soil profile development consists merely in rearrangement of the mineral and organic soil constituents, complete or partial removal of some of them from the soil and, in some cases, addition of materials from others. In the first place, obviously, soils are determined by the rocks from which they are derived, and these differ widely in chemical and physical constitution. But the character of the climate eventually alters the nature of the soil, as we have already seen to some extent from nearly all kinds of rock so much so that the mature soil type is similar in its main features throughout a given climatic region, whence it may be said that the mature soil type is determined as much, and in some cases, more by climate than by the nature of the original rock. And of all factors of climate, the most important effect on the genesis of soils are those which are brought about by water, particularly, in the case of arid and semi-arid regions. Soil moisture conditions depend on several factors, of which the amount and rate of precipitation are of prime importance. If a 5 cm rain falls slowly and is spread out evenly over a period of several days, the soil has an opportunity to absorb a large proportion of

it. If, on the other hand, the same amount falls in half an hour — and this often happen in some parts of North China — only a small proportion will be absorbed by the soil, the remainder running off to the rivers, carrying with it a considerable part of the topsoil and leaving the deeper layers dry. Much emphasis has been laid upon the water content of soil as directly determining the character of vegetation and its rate of development.

It is the dissolving and hydrolyzing effect of the percolating soil water that has such an important effect on soil profile formation and on the weathering of parent rocks. Depending, thus, upon the nature of the climatic environment, we find three general processes of zonal soil development, namely, (A) calcification, (B) podzolization, and (C) laterization.(1)

(A) **Calcification**

Calcification is that process by which calcium carbonate and calcium-rich colloids accumulate in the soil, which process of soil development occurs most typically under grasses or grass-like vegetation. The kinds of grasses and their abundance not only determine the degree of calcification, but also the content of organic matter and thickness of the soil itself. That is, since the grasses absorb and transport bases from the lower soil horizon to the surface in relatively large amounts, the soil does not become acid, or if so, only slightly acid, and the colloids, both organic and inorganic, in the presence of abundant calcium are not elutriated. There is little or no movement of clay or other colloidal material from the A to the B-horizon.

The absorption and fixation of organic complexes in the soil depend largely upon the calcium content of the soil, because a certain amount of calcium can be saturated with humus to the extent of its calcium content. Each type of soil has, therefore, a specific degree of saturation with humus.(2)

In subhumid and semi-arid climates, such as those obtaining in most of North China, the rainfall is insufficient to leach the lime from the soil. In the well developed soil of Inner Mongolia and parts of Manchoukuo, the lime has been leached from upper horizons and part of it deposited somewhere in the subsoil, and these are used in marking up the calcified layer or consolidated substance like doll or twigs, called "Loess-doll" (cf Fig. 12).

(B) **Podzolization**

Podzolization is the process by which the "ashygray" Podzols and the

(1) KELLOGG, C. E.: Development and significance of the great soil groups of the United States. U. S. Dept. Agric., Misc. Pub., (1936) 229.
(2) WAKSMAN, S. A.: Humus. (1936) 361–396.

very numerous Podzolic Soils are formed — a process typically active in the northern, humid, cold-temperate regions on heath lands and, especially, in coniferous forests where precipitation exceeds evaporation, resulting in an acid soil, and an acid-humus producing flora. Podzols are sometimes also well-developed under hardwood and mixed hardwood and coniferous forest. Podzolization therefore has a very important effect on large areas of soils in all the humid parts of northern East-Asia, for example, eastern Manchoukuo and the Russian Maritime Province. In these regions, there is sufficient moisture to romove the soluble salts completely from the soil. Trees, especially the *Coniferae*, absorb much less of the bases than does grassland vegetation. Conifers have a lower content of bases in their leaves and twigs, which are shed slowly, than do the broad leaves of deciduous trees. Because not enough bases are returned to the surface soil to prevent it from becoming acid, the colloids become either partly or almost wholly saturated with hydrogen. The occurrence of Podzol is thus intimately connected with the vegetation of a region.(1) The podzolization process consists essentially of leaching and elutriation of iron and alminium compounds from the upper part of the soil and the partial deposition of the leachings in certain parts of the subsoil. This is accompanied by the elutriation of clays from the upper horizons and their deposition or illuviation in the subsoils. The process often involves similar migration of organic matter, which often helps to keep the iron in suspension. In strongly podzolized soils the greater part of the monovalent and divalent cations are removed from the soil materials by leaching.

(C) Laterization

Laterization is the process, the ultimate product of which is Laterite. From a chemical standpoint, laterization essentially, is a leaching of alkalies and alkaline earths and of combined silica, and the accumulation of the hydroxides and sesquioxides of aluminium and iron. A unique character is the presence of aluminium as aluminium hydroxide with a composition of about 65 per cent alumina and 35 per cent water. This is in strong contrast to most soil types in which the aluminium is in the form of complex aluminium silicates of the alkalies or alkaline earths, or as simple aluminium silicate, a decomposition product of these. Iron is often present in abundance as hydrated ferric oxide, giving the bright red color of many Laterites, which is not how-

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(1) WILDE, S. A.: The relation of soils and forest vegetation in the Lake States region. Ecology, **14** (1933) 94–105.

ever, as is sometimes supposed, an invariable character of this soil type. The prevailing high temperature tends to oxidise the iron and the abundant moisture to hydrate it. Laterites, therefore, are ordinarily red or brownish-red in the upper horizons, while the subsoils are reticulately mottled and streaked with red, buff, and white, often to several meters depth. Laterites usually consist of clay-sized particles, and when blocks of the material are cut out and exposed to the sun and air they harden into bricks. Slag-like iron-stone crusts are very common either near the surface or in the subsoils. Fully developed Laterites are nowhere of great importance in the regions under consideration, seeing that they are, essentially, tropical or subtropical soil developed under a hich rainfall (probably a minimum of 1300 mm), and more highly leached than any other soil group. Typically, also, they are thoroughly elutriated, so that a light surface layer overlies a heavy subsoil. There is a low percentage of humus, owing to the very favourable conditions for its decomposition. Laterites are formed from a variety of rocks, among which basalt, slightly impure limestones, and various other basic rocks are the most common.

(D) Classification of soils

Under different degrees of influence of these three processes above mentioned, respectively or in combination, various kinds of soil groups have been developed in the regions concerned, so that the possibility of grouping these soils might be recognized in many different ways, some of which might have just as much merit as that used here. The writer has taken up the following classifications closely related to that usued by J. THORP (1936) for the soils of China, by K. TUKUNAGA (1934) for that of Manchoukuo, and by DOKUCHAIEV and his colleagues for the U. S. S. R., although in origin these classifications, particularly in regard to the broader groups, are based on the system developed by Russian pedologists.

By this classification, two important larger groups of soils are recognized, at first, in the regions concerned, one comprising the slightly leached or unleached soils, and the other, the moderately to strongly leached soils. The former group corresponds very closely to MARBUT's "Pedocals" and de' SIGMOND's "Calcium Soils", while the latter corresponds closely to MARBUT's "Pedalfer" and de' SIGMOND's "Hydrogen (acid) Soils". Soils of the first group, which have a neutral or slightly alkaline reaction, have not been thoroughly leached. They occur in climates ranging from subhumid to arid,

except in the case of a few special types, which owe their characteristics to peculiar parent rocks or to their extreme youth. On the other hand, the second group is more or less acid in reaction and, as their name indicates, are moderately to strongly leached. They nearly always occur in regions where the climate is either moderately or very humid.

For convenience of discussion the writer will call the first group the "Calcareous and poorly-leached group" and the second the "Non-calcareous and leached group".

List of Soil Classfication

(1) Calcareous and poorly-leached groups (Pedocals) — Under the influence of Calcification —

(a) Chernozems (Black Earths)
- (i) Normal Chernozems (B.)
- (ii) Degraded Chernozems (D. B.)
- (iii) Quasi-Chernozems (Q. B.)

(b) Chestnut Soils
- (i) Dark Chestnut Earths (C.)
- (ii) Light and Very Light Chesnut Earths (L. C.)
- (iii) Imperfectly developed Chestnut Earths (loessial origin) (I. L. C.)

(c) Desert Soils (D.)

(d) Aeolian Sand (A. S.)

(e) Alkali Soils (S. D. C.)
- (i) Alkaline Soils (Solonetz)
- (ii) Saline Soils (Solonchak)

(2) Non-calcareous and leached groups (Pedalfers) — Under the influence of Podzolization or Laterization —

(a) Podzols (P.)

(b) Podzolic Soils
- (i) Gray-brown Podzolic Soils (G.)
- (ii) Shantung Brownsoils (Br.)

(c) Terra Rossa (T.)

(d) Bog and Tundra Soils (M.)
- (i) Bog Soils
- (ii) Tundra Soils

(e) Dark colored Alpine Soils (A.)

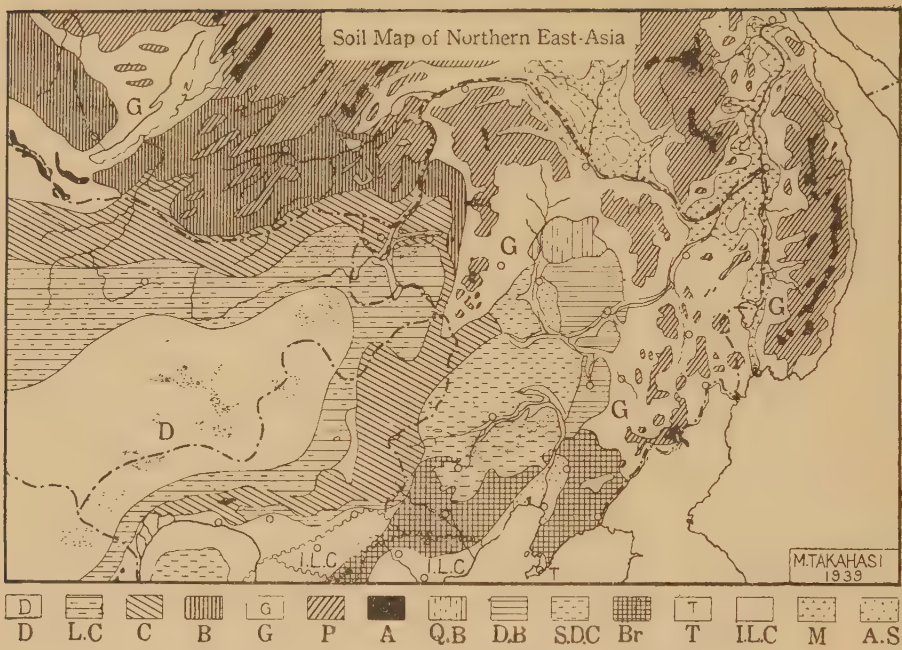

Fig. 13. Soil map of northern East-Asia.

D. Desert Soils
L. C. Light and Very Light Chestnut Earths
C. Dark Chestnut Earths
B. Normal Chernozems
G. Gray-brown Podzolic Soils
P. Podzols
A. Dark colored Alpine Soils
Q. B. Quasi-Chernozems
D. B. Degraded Chernozems
S. D. C. Alkali Soils
Br. Shantung Brownsoils
T. Terra Rossa
I. L. C. Imperfectly developed Chestnut Earths
M. Bog and Tundra Soils
A. S. Aeolian Sand

(1) **Calcareous and poorly-leached groups** (Pedocals). — These groups are found under the influence of Calcification.

(a) **Chernozems.** This group of soils, one of the most important in the world, is found in the most humid part of drier regions having soils with a calcium carbonate horizon. They develop under a continental climate, usually with a small excess of evaporation over precipitation.

(i) **Normal Chernozens** (B.). In the northern part of East-Asia, typical well developed Chernozems occur, chiefly in the grasslands of southern Siberia[1]

(1) These Chernozems form a large belt, extending from the northwestern parts of the regions under consideration westward to the foot of the Carpathian mountains in Europe.

and in small areas in the northern part of Hsingan-Peh-Sheng (興安北省) in Manchoukuo, for example, in the San-Ho (三河) region. These soils are developed on lands covered with tall grass vegetation. But much of the Chernozems have already been put under cultivation and are well adapted for this purpose. In these places they occur in very close association with Dark Chestnut Earths, and are subordinate to them in the matter of area; they will be referred to again in the next paragraph.

The characteristics of Chernozems are summarized as follows:—These soils have a relatively high organic matter content, which gives them their black color. They are very dark-brown to almost black soils to depths varying from 20 or 30 cm to more than a metre. Textures vary from sandy loam to loamy clay, the soils being friable. No organic matter is present in the same concentration in the various soil layers; it diminishes with depth. There is further no sharp line of demarkation between the dark surface soil and the light-colored subsoil. The humus content of the black soils is usually between 6 and 10 per cent, but sometimes less than 4 per cent, especially over sandy subsoils, or as high as 20 per cent and more.

The organic matter of Chernozems is amorphous, microscopic examination showing only that they are of plant origin, derived mainly from grass plants. The grass roots, which form a thick mat in the upper part of the soils to a depth of 20 or 30 cm are usually very plentiful to the bottom of the black A-horizon. Since the soil does not show any regular stratification, it is impossible to regard these humus formation as water deposits. The occurrence of humus in the lower layers is explained either by the decomposition of roots or by the washing down of some of the organic constituents from the surface layer. Thus, the luxuriant grasses have exerted a powerful influence to build up the soil profile. In addition, the deep distribution of humus through the profile is due in part to the action of earthworms, insects, etc., and the extensive burrowing of rodents.

The continuous annual growth of plants, both on and below the surface, is accompanied by a gradual decomposition of plant residues. The temperature and moisture of the grassland in the Chernozems Regions favour abundant growth of grasses, but not rapid decomposition of the organic residues. The highest humus content of these soils is shown to occur in the center of a broad grassland belt in Siberia, the contents becoming progressively lower in the soils northward and southward.

In the typical Chernozems, although all the free lime has been leached

from the A-horizon, the colloidal fraction of the soil still contains a high proportion of absorbed calcium ions. Beneath the A-horizon is a yellowish-brown to light brown material of texture similar to that of the A-horizon, which last is streaked and mottled by an accumulation of silty or concretionary lime, or both. The horizon of these accumulations usually occur at a comparatively low depth because Chernozems are formed in a subhumid to semi-arid climate and are highly leached. That is, under these environments calcium and magnesium are brought to the soil surface by the grasses, and after their death and decay the elements are united with carbonic acid to form their respective carbonates, which are never leached beyond the depths of the roots of the grasses, namely, the general depth of water penetration. During the rainy season, the percolating water is highly charged with carbon dioxide liberated from the decomposing organic matter. This converts the calcium carbonate into soluble and unstable bicarbonate, which is leached downward. Upon drying of the soil, it is deposited as calcium carbonate. Since this water is not so highly charged with carbon dioxide, it remains undissolved by any capillary water moving upward, the only upward movement being, therefore, through the plants.

The parent materials of Chernozems are numerous. A soil judged in the field to be a Chernozem, in the San-Ho region, was derived from a mixture of disintegrated granite and wind blown dust. In the Manchurian Plains one of the most common of these is a deep loess-like deposit, although a large proportion of the black soils derived from this material does not belong to the typical Chernozems, but to a degraded type.

(ii) **Degraded Chernozems** (D. B.). In Degraded Chernozems, the free lime has all or nearly all been leached away under the influence of an encroaching forest that tended to produce acid soil conditions, and the organic matter of the upper horizons is gradually disappearing. In these regions, dust storms bring a little lime to the soil, but not sufficient to make it calcareous. At present, they are nearly all either covered by long grass vegetations forming a kind of Prairie, or are under cultivation. The area of these soils have more rainfall than a normal Chernozem region.

Black soils of this kind are observed also in a narrow and discontinuous strip along the southern edge of the Mongolian Plateau, being derived chiefly from basalt, trachyte, or porphyry, with considerable wind-blown materials comprising chiefly sands and silt,

(iii) **Quasi-Chernozems** (Q. B.). Soils of this kind, which are likely to be

almost as productive as the normal Chernozems, have practically little or no lime accumulation anywhere in their profiles. It will be noted that there is a strong leaching of lime in the entire profile, and that there has been only a slight downward movement of colloids. These soils have comparatively less pH than Degraded Chernozems whose high pH is probably a reflection of local conditions.

(b) **Chesnut Soils.** From the regions of Chernozems, with decreasing precipitation, centripetalward to the Gobi proper, the vegetation becomes sparser, the soils become lighter in color, and the solum thinner. They comprise light brown to dark brown soils, rich in carbonates, without containing, however, any sodium in their adsorbing complex. They contain, according to GLINKA, 3.5–4.5 per cent humus in the surface layer, there being a rapid decrease of humus content with depth, so that at 35–45 cm it is only 0.94 per cent. That is, in the present regions inside the Chernozems zone, in progressively drier climates we find Dark Chestnut Earths having tall grass vegetation and Light Chestnut Earths of short-grass vegetation, Very light Chestnut Earths of semi-deserts, and finally Desert Soils.(1)

The darkness of the soil is an expression of the density of the grass cover under which they developed. This, in turn, is the result of precipitation, the higher rainfall supporting the densest cover of vegetation, the lower the most sparse. On his soil map it has been necessary to combine the second and the third group under the title of "Light and Very Light Chestnut Earths" because of the great geographic overlap that occurs between them.

Although in Inner Mongolia, from 15 to 30 cm of the dark colored horison has been leached free of its lime, the lower part usually effervesces slightly with dilute acid, and is darker colored than the leached surface soil. The lime layer decreases in depth with decreased precipitation, the influence of vegetation on soil development becoming less and less.

The typical Chestnut Earth is characterized by moderately deep surface soil of colors varying from dark brown or dark grayish-brown to light or very light brown, according to the subgroup to which they belong, and very calcareous subsoils which normally contain more lime than the parent materials.

(i) **Dark Chestnut Earths** (C.). These occur chiefly in Inner Mongolia, northwestern Manchoukuo, and, in all probability, in the widely scattered favourable climatic regions of Outer Mongolia. They occur where soil moisture

(1) NIKIFOROFF, C. C.: General trends of the desert type of soil formation. Soil Science, **43** (1933) 35–58.

averages somewhat less than in the case of Chernozems, and where there is a mixed short and tall grass vegetations, forming a kind of steppe.

Within even the region of Dark Chestnut Earths we find many areas of lighter colored soils on the convex slopes and hilltops where drainage is excessive and vegetation more sparse. In the moister valleys, the soils are sometimes colored sufficiently to be classed as Chernozems; and, where drainage is poor, Saline and Alkaline Soils are common. In regions where loess is gradually accumulating, the surface horizons are calcareous. Beneath the dark colored A-horizon is a horizon of varying thicknesses, containing a high percentage of calcium carbonate, usually consisting of a soft and silty deposit, but sometimes gathered together in the form of hard lime concretions. The parent materials vary, including basalt, trachyte, porphyry, granite, alluvium and, in a few cases, loess.

(ii) **Light and Very Light Chestnut Earths** (L. C.). These occur under climatic conditiohs varying from semi-arid to desert. Most of the soils of this group are more or less sandy in texture. In the sandy types, the upper 10 or 20 cm, which, usually, has been leached free of lime and is somewhat lighter colored than the lower part of the A-horizon, which extens to a total depth of from 30 to 40 cm.

The Very Light Chestnut Earths are the same as the Light Chestnut Earths in all respects except in the dark color of the A-horizon and in the average depth of same. As mentioned in the preceding paragraph, much of the Chernozems in the regions concerned have already been put under cultivation, being well adapted for this purpose. The Chestnut Soils, however, have a somewhat different story. These soils, although notably rich in the elements needed for crop production, occur in regions that are marginal for agriculture, so far as climatic conditions are concerned. In years of sufficient rainfall and of not too cold a temperature, farmers in Inner Mongolia raise splendid crops of potatoes, oats, and spring wheat. When rainfall is somewhat less, crops are greatly reduced, barring, however, except those in the valleys and on concave slopes, where soil moisture is somewhat plentiful, except for the developing Alkali Soil. As J. THORP[1] has already pointed out, it may well be thought that Dark Chestnut Earths are the limit beyond which cultivation should not be permitted to extend.

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(1) THORP, J.: Geography of the soils of China. (1936).

Fig. 12. Consolidated calcifyed substance like doll, called "Loess-doll" (face P. 480). (M. TAKAHASI)

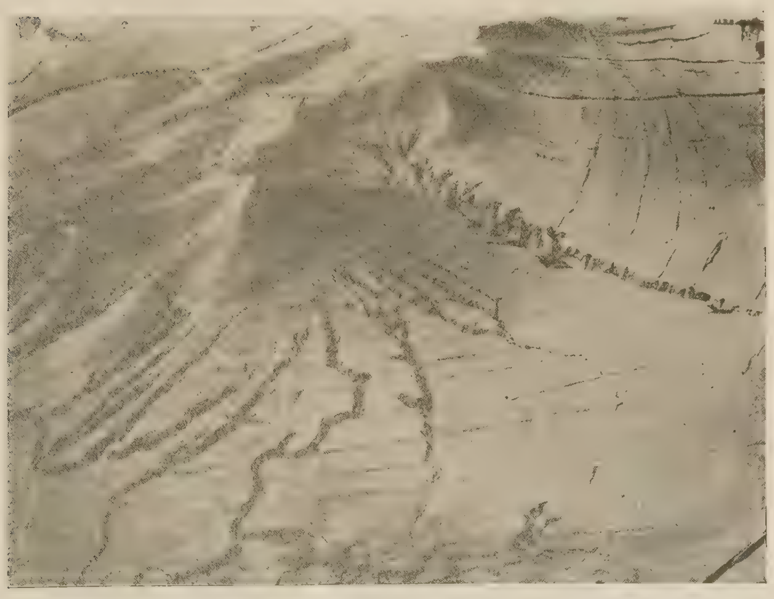

Fig. 14. Soil of loessial origin in Jehol is being rapidly eroded by heavy rains (face P. 491). (Publication permitted by the authorities)

Fig. 17. A vegetable-garden under irrigation fresh water, in Mongolia (face P. 494). (M. TAKAHASI)

Fig. 18. A cliff of red clay called the "reddish phase", an important variation of Gray and Yellow-gray Desert Soils (face P. 494). (M. TAKAHASI)

But cultivation in a few places in Inner Mongolia has now extended beyond the limit of Dark Chestnut Earths.

We find remnants of three ancient "great walls" extending across the rolling plains or montain ridges of Inner Mongolia and far northern China from the border of Manchoukuo as far west as Ninghsia (寧夏) Province. The first of these is within the border of the Dark Chestnut Earths, the second, slightly beyond the edge of these Earths, and the third, low and sinuous ridges resembling abandoned dikes, near the boundary dividing the Light and Very Light Chestnut Earths.

(iii) **Imperfectly developed Chestnut Earths** (loessial origin) (I. L. C.). In addition to the normal well developed Chestnut Earths we meet with vast areas of imperfectly developed soils in which there has been much less leaching of lime from surface horizons and redeposition in subsoils.

This immature Light and Very Light Chestnut Earths are of great natural fertility, so far as mineral plant nutrients are concerned, but they lack organic matters. It is very probable that the long dry annual season and the porous structure of the soil contribute to the oxidation and disappearance of the organic matters derived from plant decay.

As already mentioned in the chapter "The Regions under Consideration", there are large areas of land in northern and eastern Kansu (甘肅), central and northern Shensi (陝西), much of Shansi (山西), and smaller areas in eastern Tsinghai (青海), northern Honan (河南), western Hopei (河北), southern Jehol (熱河), and west-central Shantung (山東) that are covered with a thick blanket of this immature soil group, technically known as loess, which varies from a few centimeters to a hundred meters or more in thickness. However, the question has frequently arisen as to what constitutes a true loess. Should it be confined to a mere lithological definition, or should it include all fine materials accumulated through the agency of wind deposition? This question has not yet been satisfactorily answered. J. THORP prefered to regard loess as accumulations of finely divided, wind-blown dust, which may or may not have undergone varying degree of weathering since it was first deposited.(1)

All soils of loessial origin, whether belonging to this group or to the darker colored types, are being rapidly eroded, because the greater part of the loess lies on hilly lands where water run-off is rapid, especially after the heavy summer rains (cf Fig. 14).

(1) THORP, J.: Geography of the soils of China. (1935) 119.

Even in loessial regions the loess, instead of forming a continuous blanket, varies greatly in thickness, while in many places it is entirely lacking. Much of the loess is underlain by reddish and purplish soft shales and sandstones that one often sees exposed on hilltops and eroded slopes. All the loess which the writer has so far examined and analysed contained more than 20 per cent of clay-sized particles (diameters less than 0.005 mm) (cf Figs. 15 & 16).

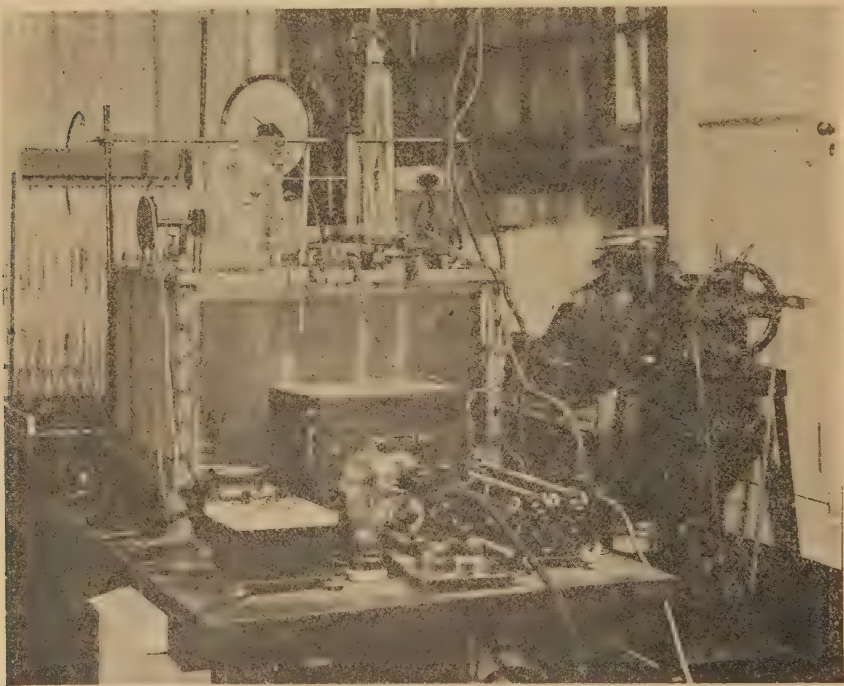

Fig. 15. The writer's apparatus of measuring soil particles by sedimentation method.

This loess is all very calcareous except in a few places in the more humid parts, where a part of the lime has been leached out. The remainder is covered by soils showing profiles of only very slight degree of development. These soils have developed in a climatic region where one would expect a good grasscover and darker colored soils. The hilltops receive somewhat more rainfall than the adjacent lower lands, usually, the former having, besides, more frequent periods of foggy weather and cooler average temperature. All these factors contribute to a moister condition in the soil which, in turn, is able to support a denser grass vegetation than the drier loessial deposits adjoining it. In this connection there is another factor of great scientific

interest. It is the difference between the north and south-facing slopes, vegetation being much denser on the former slopes than on the latter, the soils everywhere being almost darker colored except where the moisture is sufficient to support heavy forest growth.

(c) **Desert Soils** (D). The color of soils of the Light Chestnut Earth zone becomes lighter toward the inner drier regions, namely, Gobi proper. There is, however, no sharp line of division between the different soil groups; the boundaries shown on the map should be regarded as belts of land rather than as sharp dividing lines. The important soil groups observed in the desert regions may be divided into six groups; (i) Very Light Chestnut Earths, (ii) Gray and Yellow-gray Desert Soils, (iii) Reddish Clays, (iv) Stony Desert Lands, (v) Aeolian Sands, and (vi) Alkali Soils. Except the two groups, namely, the Gray and Yellow-gray Desert Soils and Stony Desert Lands, some of these soils occur in true desert regions, while others are found in semi-deserts, which may explain why not only the climatic factors are intimately related to the characters and features of general soil groups, but also that local differences in topography, natural drainage, and texture of soil materials jointly cause local soil differences.

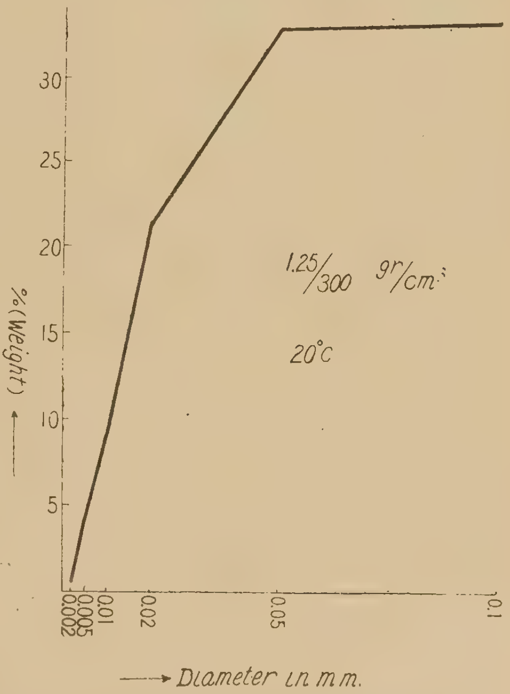

Fig. 16. Sizes of particles and distribution curve of a loess by sedimentation method (face P. 492).
(M. TAKAHASI)

The writer has already discussed Very Light Chestnut Earths, some of which are quite common in regions covered by a sparse growth of short grasses, these extending even to region of brushy semi-deserts in some places.

Yellow-gray Desert Soils have a thin whitish surface crust a few millimeters thick, underlain by yellow-gray porous and granular soil which is usually very calcareous. This yellow-gray material merges into the under-

lying yellowish loess or other parent materials. Frequently subsoils are sandy. Sometimes the surface horison of the Yellow-gray Desert Soils comprises a "Desert Pavement" of small angular stone fragments or gravels that have accumulated as a result of winds blowing away the smaller sized particles of soil. The pavements also extend into the semi-arid regions where Light Chestnut Soils occur. They are not so well developed in this region and nothing of the sort is observed on the Dark Chestnut Earths, probably because the grass vegetation prevents serious wind erosion. Other large areas, particularly in the middle of the Gobi Desert and in the mountains of the desert borderlands, comprise a great expanse of stony outcrops with pockets of sand dunes. The former soils, having blown away, are deposited elsewhere as loess.

The Gray Desert Soils are formed under the conditions of a dry and continental climate, with hot summers, cold winters, and no precipitation in summer. The high summer temperatures and constant winds dry out the soil, while the sparse vegetation leaves comparatively little residual material, which is itself rapidly decomposed, so that the organic matter content of these soils is usually very low, from 1.5 to 0.2 per cent and even less. Yellow-gray and Gray Desert Soils are very extensive in Mongolia and Sinkiang (新疆), where the bulk of them would doubtlessly make good farmland if more fresh irrigation water were available (cf Fig. 17). But in these regions, after a few years of cultivation, the troublesome phenomena of the socalled "Alkali accumulations" are often experienced.

An important variation of Gray and Yellow-gray Desert Soils might be called the "reddish phase" of these types (cf Fig. 18). In places where reddish clays of various geological age (usually one of the divisions of the Tertiary) are exposed to soil weathering, we find a thin, pale reddish-brown or light red granular soil, usually low in lime and sometimes containing small crystals of gypsum. Gypsum deposits in the soils of the deserts are quite common in many places, especially along the edges of alluvial fans and on slopes surrounding areas of low-lying Alkaline or Saline Soils. They seem to be due to gradual accumulation brought about by the evaporation of saline waters.

In addition to the types already discussed, we have the "Desert Pavement",—a feature of the soils in deserts or semi-deserts, which are very common in Gobi, and the Tarim (塔里木) and Tsaidam (柴達木) Basins.

The Aeolian Sands and Alkali Soils, which are also common in deserts, will be discussed in a separate chapter.

(d) **Aeolian Sand** (A. S.). Generally speaking, sand dunes and sandy plains which consist mainly of Aeolian Sand, all show the same development, regardless of their differences in form. Tracing their origins, sand dunes and sandy plains may be classified into five groups, namely, the inland, the sea-coastal, the riverside, the lakeside, and the glacial dunes, the firstnamed two being the most important at the present time.

In both groups we find that the wind-blow sand has an uniform type of vegetation. Glaciers, which often cause extensive deposits, have been of the greatest importance in the past, although today their action is localized in the mountains and polar regions, as is also that of snow and ice. They deposit soil materials that show all possible degrees of variation.

Although the wide distribution of dunes and their striking mobility have made them favourite subjects of investigation, from the ecologieal point of view, dunes, the world over, are very similar in their vegetation, or at least in the growth-form of their plants. Sand dunes affect the succession of vegetation there by virtue of their instability, water relations, kind and amount of holding salts, and not by the variety of their forms or origins.

In the present regions, sand dunes occupy much land in the northeastern Ordos (鄂爾多斯) and Alashan in the southeast Ningsia (寧夏), the former dunes of the southeastern part crossing the Great Wall north of Yulin (楡林) in Shensi (陝西) and menacing the agricultural lands of the region as well as the town itself. Residents of Tolun (多倫) in Inner Mongolia are trying to stem the tide of advancing sand dunes, constituting a part of Kunshantung (渾善達克) Sandy Land, north of the city (cf Fig. 19). Belts of very sandy land are also common near the banks of such rivers as the Hwang (黃河), the Wei (淮河), the Hsilamulün (西喇木倫河), and many others in western Hopeh (河北), northern Shantung (山東), and the southwestern parts of Manchoukuo. This is especially true of the region near Kaifeng (開封), Honan (河南), where the Hwang has thrown up a vast amount of loose yellow sand and spread it over a large area of formerly productive land. When the rivers are again confined to their banks, these loose sands are piled up into dunes by the winter and spring winds, the dunes moving slowly but relentlessly over the land, burying farms, orchards, and farm houses (cf Fig. 20). Fortunately, the total area of migrating sand dunes is not great when compared with the total area of alluvial land in North China.

The soil map of northern East-Asia (cf Fig. 13) shows the approximate location of some of the important sand dunes and sandy plains.

(e) **Alkali Soils** (S. D. C.). Alkali Soils are local, intrazonal soil groups, not zonal soil types. They occur in regions that are receiving, or have received at some time, an excess of salts. They are areas of periodic excessive moistening and drying. These salts have originated from the soils derived from the native rock. In humid or semi-humid regions the excess salts have been leached out by rain and finally accumulated in the ocean. In arid or semi-arid regions, on the other hand, the ground water is usually more or less salty, and since this water rises to the surface by capillary attraction, it evaporates, leaving the salts in the soil. Alkali Soils include so much soluble salts, regardless of their specific reactions, that the salts concentrate sufficiently to injure common plants. They include the chlorides, sulphates, carbonates, and nitrates of sodium, potassium, and magnesium, and the chloride and nitrate of calcium. Thus, even sodium nitrate, an important constituent of fertilizers, if in excess, produces a kind of Alkali Soil. Since, with the exception of the carbonates or bicarbonates, all the soil salts are neutral in reaction, those containing an excess of any of these neutral salts are more properly designated Saline Soils (Solonchak).[1] They are known collectively, however, as white Alkali, from the white incrustations they usually produce.

The saltiest spots of soil are those that occur in poorly or imperfectly drained areas where the slightly saline subsoil waters are near enough the surface to be drawn up by capillary action and evaporated. On the other hand, the Alkaline Soils containing carbonates of sodium or potassium are called Black Alkali (Solonetz), because of the dark-colored incrustations which these salts produce by their solvent action on the organic matter of the soil. But, in many places where vegetation is sparse, the color is brown or dark brown instead of black. These Solonetz Soils are characterized by a somewhat leached surface soil a few centimeters thick, underlain by a heavy, stiff, and plastic subsoil that is practically impervious to water.

Under certain specific climatic and topographic conditions, a decrease in soil moisture results in the accumulation of soluble salts and alkali carbonates, with the result that calcium and magnesium are gradually replaced by sodium in the absorbing complex. The humus part of the complex is also gradually reduced, in contrast with the changes in Chernozems, and its place taken by alumino-silicates.[2]

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(1) The salts most commonly present in Saline Soils are sodium chloride and sodium sulphate. There are several other less common salts.

(2) GEDROIZ, A. K. : The soil absorbing complex and the absorbed cations of the soil as a basis for a genetic soil classification. Kolloidchem. Beih. **29** (1929) 149.

Fig. 19. Residents of Tolun (多倫) are trying to stem the tide of advancing sand dunes by fences of *Salix Kochiana* or *S. mongolica* (face P. 495). (M. TAKAHASI)

Fig. 20. The Hwang-Ho has thrown up a vast amount of loose sand and spread it over even castle-walls (face P. 495). (M. TAKAHASI)

Fig. 21. *Quercus mongolica*—Sociation on Gray-brown Podzolic Soils
(face P. 502). (M. TAKAHASI)

Fig. 22. Cultivation of cotton plants on Shantung Brownsoils
(face P. 503). (M. TAKAHASI)

Saline Soils (Solonchaks) are thus produced, followed by the formation of Alkaline Soils (Solonetz), when the clay and humus are mainly saturated with sodium. On the contrary, desalinization, that is, removal of the excess salts as by drainage, and alkalinization (hydrolysis of sodium to sodium hydroxide and its reaction with carbon dioxide to form sodium carbonate) changes a Saline Soil (Solonchak) to a deflocculated Alkaline one (Solonetz).(1)

Notwithstanding the same concentration, Alkaline Soils are much more harmful to plants than Saline Soils, because they contain sodium carbonate, which has a higher pH value. Independent of this pH value, a concentrated soil solution, owing to excess of salt and to loss of water by surface evaporation, may, by hindering water absorption, delay seed germination either temporarily or indefinitely.

Salt water plants, for example, seaweeds, mangroves, etc., have certain adaptations, such as high osmotic pressures or mucilaginous cell contents, etc., characteristic of Halophytes.(2) The seeds of most Halophytes probably germinate only when the soil solution is diluted by rains. If germination is successful, a later concentration of salts may cause the movement of water from the root hairs to the soil, giving rise to a condition of plasmolysis; absorption being inhibited, wilting and death may result. Even if the plants can grow, unless they have become adapted to the excess supply of ions into which the salts are dissociated, their nutrition is disturbed. Saline Soils have very little agricultural value unless reclaimed. These two kinds of Alkali Soils are very widely distributed over North China, Mongolia, and western Manchoukuo. One meets with all sorts of variations between Solonetz and Solonchak in Inner Mongolia—especially in a large area just north of Changpeihsie (張北縣) city. The salts of the soils of eastern Kiangsu (江蘇) are chiefly sodium chloride, with some sodium sulphate and a little sodium bicarbonate. The small quantities of potassium nitrate or saltpetre found in some places are gathered and used for gunpowder. Except in a few places, sodium carbonate occurs in only very small quantities. On the alluvial plains, where rain water run-off is slow and where the water table is usually fairly high, a slight difference in the level of the land may make a large difference in the salt content of the soil.

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(1) KENOYER, L. A.: General and successional ecology of the lower tropical rain-forest of Barro Colorado Island, Panama. Ecology, **10** (1929) 201–222.

(2) WALTER, H.: Über den Wasserhaushalt der Mangrovepflanzen. Ber. Schweiz. Bot. Ges., **46** (1936) 217–228.

In the present regions the process of salinization is not confined entirely to dry regions. Along the seacoast of Pohai Bay (渤海灣) and in the outer edge of the great delta region of eastern Kiangsu (江蘇) from Haichow (海州) southward, there is a belt of saline soils that extends well into the humid warm-temperate region. Here the sea water keeps the soils in saline condition both by seeping in from the ocean and from tidal estuaries, and in the summer and early autumn months, by blowing in and flooding the land during typhoons.

(2) **Non-calcareous and leached groups** (Pedalfers). — These groups are found under the influence of Podzolization or Laterization.

(a) **Podzols** (P.). The essential feature of a Podzol profile is its division into three main horizons, usually including several minor ones, more or less sharply differentiated from one another. A layer of organic matter (A_0-horizon), consisting of leaves of trees and other forest debris, covers the surface to a depth varying from 2.5 to 30 or more cm. The material is brown, acid in reaction, and only partly decayed. This raw humus layer may be sharply divided from the mineral soil underneath, but usually the upper part of the mineral horizon contains more or less partly decomposed organic matter. The upper part of the mineral soil (A_1-horizon) is very thin and dark gray. The lower part (A_2-horizon) ranges in thickness from a mere film to 30 cm and more, and light gray. Thus, the surface of the Podzol has been impoverished of bases, colloids, and nitrogen;[1] virtually nothing but silica remains in this leached horizon.

The B-horizon, which has greater consistence, is reddish, brown, or nearly black, the thickness varying from a mere film to several centimeters. The color becomes lighter with depth, shading off gradually into that of the underlying parent material. This horizon has been enriched by the addition of eluviated organic matter, compounds of iron and aluminium, etc. This soil is usually acid in reaction. An intimate correlation is found between the acidity of Podzols and the organic matter content of the soil.[2]

A larger part of the acid-reacting substances in the A_1-horizon can be removed by percolation with distilled water. The sulphate and phosphate ions

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(1) TAYLOR, R. F.: Available nitrogen as a factor influencing the occurrence of sitka spruce and western hemlock seedlings in the forests of southeastern Alaska. Ecology, **16** (1935) 580-602.

(2) ATKINSON, H. J. and R. R. MCKIBBIN,: Chemical studies on Appalachian upland podzol soils. II. Organic matter acidity relations. Can. Jour. Res., **11** (1934) 759-769.

are sufficient to account for the major part of the acidity of the water extract. These acidic Podzols are very detrimental to insect life, earthworms, and bacteria, low temperatures and poor aeration being the contributing factors, the tannins from coniferous trees being also supposed to have a toxic action, especially to bacteria, which are almost entirely replaced by the more acid-enduring fungi. These may grow in such abundance that their mycelia may be seen interwoven among the layers of raw humus. Decomposition of organic matter by fungi leads to the production of organic acids and relatively soluble substances, and to the reduction and solubility of iron. Since, normally, under conditions of good drainage, the soluble irons move downward, become oxidized, and accumulate in the B-horizon, concentration of iron; and frequently that of aluminium, the solubility of which rises rapidly with increasing acidity, occur in the B-horizon. A large proportion of the colloids, both organic and inorganic, are likewise precipitated in this horizon.(1)

Three types of Podzols are distinguished:

(i) The Iron Podzol, in which the A_1-horizen is composed of raw-humus, and is usually less than 10 cm thick.

(ii) The Iron-humus Podzol, with a high humus content in the B-horison, where it may reach 22 per cent, the humus being completely soluble in ammonia. The A_1-horizon being 5 to 30 cm thick, usually consists of moist raw humus or peat.

(iii) Humus Podzol, with the A_1-horizon consisting of peat or moist raw humus. The rate of podzolization largely depends on the vegetation. In the case of forests, the undergrowth also plays an important part. In northern and northeastern Manchoukuo, eastern Siberia, and the Russian Maritime Provinces, the regional distribution of the coniferous forest approximately agrees with the distribution of these Podzols. The absorbing roots of coniferous trees are often largely confined to the surface layer of raw humus. A pronounced beneficial effect upon the soil profile may be brought about by converting the coniferous forest into stands of hardwoods.(2)

In fact, as the result of a chance in the type of decomposition of organic matter consequent to changes in the nature of the vegetation,

(1) KELLOGG, C. E.: The place of soil in the biological complex. Science, **39** (1934) 46–51.

(2) MOORE, B.: Humus and root systems in certain northeastern forests in relation to reproduction and competition. Jour. For., **20** (1922) 233–254.

aeration, and reaction of the substratum, one soil may actually change into another.[1]

(b) **Podzolic Soils.** In these soils two subgroups are distinguishable.

(i) **Gray-brown Podzolic Soils** (G.). These soils have developed under a deciduous forest, rich in undergrowth, with a moist temperate climate (cf Fig. 21). In general, they have developed under a podzolization process but one less intense than that which gives rise to Podzols.

The undisturbed profile of Gray-brown Podzolic Soils does not include any thick layer of raw humus. The accumulation of organic matter on the surface is rarely more than 2 or 5 cm thick. Although it is better decomposed than the raw humus overlying on the well developed Podzols, usually it is not thoroughly decomposed into black, granular colloidal material. Where the forests remain, they have profiles somewhat as follows: First, there is a thin A_0-horizon comprising raw humus of partly decayed, deciduous leaves, sometimes with a mixture of conifer needles. The A_1-horizon, which is a thin layer impregnated with organic matter, is thicker than the corresponding horison of Podzols, and usually less acid in reaction. Usually, the A_2-horizon is not very distinct, and grading imperceptibly to A_1. It is lighter in color and evidently somewhat more leached, the color varying from light grayish brown to yellowish brown. These surface horizons contain much nutrient elements and organic matter, because the deciduous trees return the bases to the surface of the soil more rapidly than do the conifers. It has been estimated that a beechwood receives an annual dressing of from 5 to 7 grams of calcium per square meter but a pine forest only 2 grams.[2] Most deciduous trees maintain a steady flow of bases from the soil layers, into which their roots penetrate, to the surface, it being common silvicultural practice to include a proportion of them in a coniferous forest to reduce or prevent soil deterioration.

The B-horizon is much heavier in texture than the A, varying from clay loam to clay. Only compounds of iron and aluminium, without any organic material, have leached into the B-horizon, the color of which last depends somewhat on the nature of the parent material and somewhat on the average

(1) FISCHER, R. T.: Soil changes and silviculture of the Harvard forest. Ecology, **9** (1928) 6–11.

(2) SALISBURY, E. J.: Soil structure in relation to vegetation. Sci. Prog., **29** (1935) 469–425.

temperature of the region. It is also very responsive to slight differences in drainage, the less perfectly drained areas tending more to the yellowish than to the brown or red.

Many areas of Gray-brown Podzolic Soils have long since been cultivated or deforested and allowed to grow up into coarse grass. Where deforested soils are covered by grass there is usually a very thin surface horizon, which is dark grayish brown, and which seems to represent the accumulation of organic matter from the decay of dead grass leaves and roots. It may also be due, to some extent, to the accumulation of carbon from burned grasses. Gray-brown Podzolic Soils are especially widespread, as indicated on the soil map. Virgin Gray-brown Podzolic Soils are more fertile for agricultural crops than those of Podzols, but less fertile than Chernozems.(1) The addition of lime and fertilizers greatly increases their medium natural fertility.

(ii) **Shantung Brown soils** (Br.). These soils were mentioned by THORP in his first publication "Geography of the Soils of China".(2) The term "Shantung Brownsoils", is employed by him to include not only the typical well developed soils of the group, but also the less well developed types and those which have been recalcified in surface horizons by recent dust deposits. These soils occur on the rolling hills and rough mountains of Shantung (山東), western and northern Hopei (河北), southwestern Manchoukuo, and in small areas in northwestern Honan (河南) (cf Fig. 22). He divided the soils of this group into three subheads and several smaller divisions, which somewhat differ in profile characteristics, but not much from a practical standpoint.

1) Soils with well developed A-B-C profiles, slightly to moderately podzolized. This group has slightly acid, bright brown to dull brown loamy surface soils, which are deep and granular in structure. The subsoils are of clay texture, yellow-brown to red-brown, and stiff and cloddy. The commonest parent materials are gneiss and granite, and alluvial fan material washed from them, but there are also smaller areas derived from sandstones and shales. Where derived from alluvial fan materials, their total depth is great but where derived from rocks, they are usually less than a meter deep.

2) Soils with little or no A-B-C development in profiles. These soils, instead of being slightly acid, have an approximately neutral reaction, although

(1) ALWAY, F. J., J. KITTREDGE, and A. J. METHLEY,: Composition of the forest floor layers under different forest types on the same soil type. Soil Science, **36** (1933) 387–398.

(2) THORP, J.: Geography of the soils of China. (1936) 216–235.

there is some variation in this respect. They occur most commonly on alluvial fans and footslopes adjacent to limestone hills, where there has been a mixture of yellow-brown loess and reddish clay soil of limestone origin. The leaching has been sufficient to remove most or all of the free lime, but not sufficient to make the soils acid.

3) Recalcified phases of the first two groups. These soils having long been deforested and severly eroded, relatively speaking, a few well developed profiles may be observed. The accumulation of calcareous dust, which is especially marked in the mountainous region of western Shantung, have been furnishing an almost continuous supply of more or less calcareous dust which gradually accumulated in the region. In many places this calcareous dust accumulated more rapidly than the lime could be removed by leaching, as a result of which the soils have become recalcified in the surface horizon. Under these circumstances, in the greater part of the soil region the writer found the surface soils to have a considerably higher pH than that of the horizons lying a few centimeters below the surface. The soils of these groups are shown under one symbol on the soil map, because of the impossibility of separating them on a map of small scale.

The important differences between these Shantung Brownsoils and the Graybrown Podzolic Soils seem to be in (1) the former's low organic matter content, (2) their only slightly acid or slightly alkaline reaction when compared with the moderately to strongly acid reaction of the latter, and (3) their slight degree of profile development. The majority of the soils of these groups, so far as the writer is aware, have sufficient phosphate and potash for most crops, but are lacking in nitrogen. (cf the writer's table of chemical analyses of these soils);[1] they are moreover mostly well adapted to fruit culture, especially those of apples, pears, apricots, peaches, and jujubes.

(c) **Terra rossa** (T). In the regions concerned there are some areas of red loams that are derived partly or entirely from limestones. These soils vary greatly in profile characteristics, some of them being very young and only slightly developed, while others closely approach the character of Laterites, although these red loams differ from Laterites in containing considerable quantities of aluminium silicates, and even if aluminium hydroxide be present, its amount is small compared with that of the silicate. These red loams are usually free from iron oxide crusts, the process of eluviation not being so

(1) TAKAHASI, M.: An ecological study of vegetation in province of Jehol, Manchoukuo. Rep. First Sci. Exped. Manch. sect. **IV.** part, **III** (1936) 18.

advanced as in Laterites; they have a low percentage of organic matter. The bright red color is due, as in Laterites, to hydrated ferric oxides. They may perhaps be regarded as subtropical and warm-temperate analogues of Laterites in which, under a less heavy precipitation, the process of silicate leaching and eluviation has not proceeded so far, but the term "Terra rossa" is often applied to a wide variety of red soils, some of which are by no means mature soil types. Some are moderately or strongly podzolized, while others show little or no evidence of this process. Some are very strongly acid in reaction and others are neutral or slightly alkaline. THORP wrote—"If we use the term Terra rossa to cover all red soil of limestone origin in China, the term will have no significance except as to color. For these reasons it seems to be that the term Terra rossa as at present used is of no value. In our system of classification of soils we recognize parent material as well as other characteristics in separating different soil series." Notwithstanding this divergence in opinion, these red loams occupy the greater part of Kwantung (關東) Territory, the Cape of Liaotung (遼東), and several places in Kirin (吉林). They occur in regions of good drainage, where the water table lies several meters below the surface and sometimes are forested by *Pinus densiflora*, *P. tabulaeformis*, or some deciduous trees (cf Fig. 23).

(d) **Bog Soils and Tundra Soils** (M.).

(i) **Bog Soils** (Organic Soils). These soils, which are local, intrazonal soil groups, are found where peaty materials have accumulated under the influence of excessive moistening and deficient aeration. The term "peat" is commonly used to designate a layer of the earth's crust which is largely organic in nature and which has been formed, under certain specific conditions, from plant residues and plant products submerged in water or from plants growing in very wet environments. Thus Bog Soils are universally distributed, being most numerous in the temperate zones of cool and humid climate. In the development of peats, algae and other aquatic plants, residues of higher plants, such as spores, pollen, and leaves, as well as inorganic particles of dust, first accumulate under water, forming the bottom layer of the peat deposit. Because of the anaerobic conditions prevailing in the layer, decomposition of the plant residues does not keep pace with the new growth of plants, whence undecomposed and partly decomposed plant residues accumulate. When the level of peat accumulation has been raised by the deposit to that of the surrounding country, various herbs, shrubs, and species of *Sphagnum* grow and, eventually various coniferous trees appear. At this stage, the sur-

face of the peat is above the water level, with the result that decomposition processes begin to keep place with plant accumulation.

In the classification of these peats various systems have been proposed, being mainly based upon the following factors: (1) the nature of the plant communities growing at present on the surface of the bog; (2) the relation or peat formation to water level, namely, below or above the surface of the water; (3) the nature of the plants that gave origin to the specific type of peat; (4) the autochthonous (formed on the spot) or allochthonous nature of the plant residues that gave rise to the peat; (5) the relative concentration of nutrient elements available to the growing plants; (6) the physical and mechanical properties of the peat; (7) a combination of characteristics, such as the mechanical and physical properties and the botanical composition of the peat.

Of these factors, from the ecological point of view, (2) the relation of peat formation to water level, and (3) the nature of the plants that gave origin to the specific type of peat are recognized as the most logical basis of peat classification. From this standpoint the major types of peat may be summarized as follows:

a) Lowmoor peat. Various species of *Carex*, *Phragmites*, and *Scirpus*, as well as certain trees and shrubs are dominant; *Sphagnum* plants are either absent or rare. This type is frequently subdivided on the basis of the predominant plant, for example, *Carex* peat, *Phragmites* peat, and *Scirpus* peat. It usually occurs in places where waters, containing calcium and rich in nutrients, slowly drain into lower regions on inclined planes; it is characterized chemically by high ash and nitrogen contents, by a low cellulose content, and by low acidity.

b) Hochmoor peat. The predominant vegetation consists of various species of *Sphagnum*, *Ledum*, *Andromeda*, *Eriophorum*, and *Oxycoccus*. This type of peat, which is formed in waters originating either from atmospheric precipitation or from mineral-poor soils, carry only very low concentrations of calcium. Hochmoor peat may form on one of the other peat types, or directly on sand, clay, or rock. It is usually found in regions of cold or moderate temperatures with high rainfall. Chemically, this peat is characterized by low ash and nitrogen contents, by high contents of cellulose and hemicellulose, and by a high acidity.

c) Sedimentary or lake peat. This type of peat is formed under water, largely by algae and other aquatic plants and animals (insect shells), with an

admixture of spores, pollen, and particles of clay and sand. Althogh usually found in the lowest layers of the peat profile, it frequently forms independent peats of considerable depth. It further varies considerably in different ways, according to the nature of the plant residues, to abundance of calcium carbonate, sand, and clay; to its colloidal condition, etc. The hochmoor peats are highly acid in reaction (pH 3.5-4.5), whereas the lowmoor and sedimentary peat are less acid (pH 5.5–6.5), the latter may even be neutral.

d) Forest peat. A vegetation consisting of various trees (*Betula*, *Quercus*, *Alnus*, *Pinus*, *Picea*) ang of certain lower plants (*Salix*, *Scirpus*, *Oxycoccus*, *Andromeda*, *Carex*) gives rise to forest peat. Certain species of *Sphagnum* may form a continuous carpet in the forest. The peat is fed partly by ground waters less rich in salts than those draining into lowmoor peat, and partly by precipitation; chemically, this peat stands midway between the lowmoor and hochmoor peats.

(ii) **Tundra Soils.** The tundra stretches from the Pacific to the Atlantic Ooasts, occupying the broad zone between the tree limit and the region of perpetual snow around the North Pole. In regions where the tundra lie, frost or freezing may occur at any time during the growing period, especially at night. In consequence of low temperatures, short season, and drying winds, the plants are typically dwarfed, the dense sward often rising but a few centimeters above the level of the soil. Practically, throughout the Northern Hemisphere such vegetation like tundra occurs in contact with a boreal or subalpine forest, it being possible to recognize the former as the arctic tundra and the latter as so-called the alpine tundra, of which further later under "Tundra Formation". This is because, from SCHIMPER's idea, dwarfed growth, a distinctly xerophilous character, predominance of mosses and lichens, and the incomplete covering of ground are everywhere characteristic of the tundra.

In high altitudes where the annual temperature is below 0° C., the activities of micro-organisms are considerably delayed, and even with a sparse vegetation, the content of humus in the soil may reach 20–30 per cent, as in the case of high latitude, for humus can accumulate in well-drained and porous, that is, well-aerated soils only when the average temperature is below 25° C.; within certain limits, the lower the temperature the greater the accumulation of humus. When the average temperature is 25° C. or higher, most of the organic matter is destroyed by the lower organisms as fast as it is produced by the higher plants. In soils of tundra regions, the characteristic blue-gray layer of slightly weathered clays, silts and sands beneath the

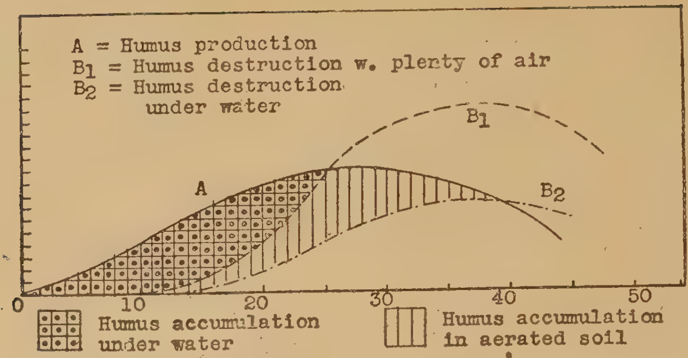

Fig. 24. Humus accumulation and humus decomposition in the soil. (after MOHR)

surface layer points to poor aeration. They are also connected with a climate sufficiently cold to prevent the slight summer thaw from extending deeply. They comprise the zonal group that occurs in regions north of the Podzols. The vegetation of sedges, lichens, mosses, etc., tends to form a surface layer of very slightly decomposed peat. In these places biological and chemical action is always reduced to a minimum, even if weathered materials consist almost wholly of rock fragments. Considerable mixing of the mineral soil and peat surface layer results from the expansion and contraction of the water-laden soil as the result of alternate freezing and thawing. Since the surface materials freeze downward, the pressure exerted on the viscous mass beneath forces itself upward through the cracks and ultimately builds up the so-called "soil-polygons" or "structured soil" (cf Fig. 25).

(e) **Dark colored Alpine Soils** (A). Most of the higher peaks of Changpei (長白山脈), Great Khingan (大興安嶺山脈), Sikhota alin, Yablonoi, and Stanovoi Mts. receive very heavy rainfall and are covered by clouds much of the time. On their summits and upper slopes the soils are kept almost continually wet, even where the slopes are fairly steep. The accumulation of humus which is the chief cause of the dark color[1] (black, dark-gray or dark-brown) of Alpine Soil is largely due to the fact that the prevailing low temperatures are less injurious to growth of higher vegetation than to activities of the micro-

(1) Humus not only imparts to the soil black, brown, and gray colors, but also modifies the soil coloration caused by iron and manganese compounds. The final color is determined principally by two factors; (i) the physical and chemical properties of the humus, and (ii) the nature of the mineral constituents; the same amount of humus darkens a gray soil much deeper than a brown or a red soil. In dry regions, the humus content is not the dominant factor in determining the soil color.

organisms that are concerned with the decomposition of the plant residues. As to accumulation of organic matter, this type of humus has nearly always been associated with forest humus. The A-horizon, which consists chiefly of plant residues and dust particles, dominates the other horizons. Some of them show evidences of podzolization in the accumulation of grayish silt beneath the dark colored A_1-horizon.

The vegetation at present largely comprises grasses, shrubs, and low trees. While the pH of these soils is usually on the acid side, some of them are almost neutral. In Wutai-Shan (五台山) even on the peaks more than 3000 m high the pH value of soils sometimes exceeds 7, because of its comparatively dry weather and influence of loessial dusts.

The meager information available concerning the distribution of alpine humus points to a parallelism between the humus content and the acidity of the soil. The high acidity of the soil and the low annual temperature are believed to be largely responsible for the wide C : N ratios of Alpine Soils. The humus of these soils is characterized by a high content of hemicelluloses and a low content of cellulose, as distinguished from the composition of fresh plant residues, where cellulose is more abundant than hemicelluloses. Strongly calcareous loess is never found in great quantity on the mountain tops and higher slopes, most of the soil materials in these places being residuals from rocks.

The general conclusion is that climate, rather than plant communities, controls the formation of humus in these soils. Our present knowledge of this group of soils is too limited to admit of further discussion.

(F) Rocks and soils

Just as there is a variety of rocks according to their different constituent elements, so there is a variety of soils that are nothing more than the weathered products of these rocks, with the result that the nutritious character of the soil is intimately connected with the nature of the rock, all of which affect vegetation, whence it follows, ecologically speaking, that one should study the geological distribution of the rock, and at the same time investigate the relationship between the rock and its weathered product, the soil, as well as the influence of this soil on vegetation. Naturally, it is not possible to determine the nature of the weathered product, the soil, by the nature of the rock alone, because, as the writer has already said, even the same rock weathers differently according to the effects of topography and climate. Some

rocks which give rise to extremely barren soil in the first and the second stages of weathering, furnish a very fertile soil at the last stage, while another rock, whose weathered product is rather sterile, becomes rich soil after it has been mixed with sandy soil brought from elsewhere. Dry soil, especially where there is only little rain, interferes with the growth of plants. It is however not absolutely impossible to accertain the general relationship between rock and soil.

For convenience, the writer has divided the rocks into the following five classes according to the characters of their weathered products, or soils:

Good …………	diabase, gabbro.
Rather good…	trachyte, melaphyre, basalt.
Medium………	porphyrite, diorite, gneiss, syenite.
Rather poor …	granite, quartz-porphyry, conglomerate. sandstone, slate, tuff.
Poor …………	limestone, dolomite, quartzite.

An inspection of the Geological Atlas of Eastern Asia(1) with the foregoing classification in mind gives interesting results. Although, in the northern or north-western mountainous regions, the southern border-land of the Mongolian Plateau is mainly formed of basalt, we find here and there hills of granite and quartzite, while the character of the soil of the southwestern areas (the greater part of North China) is influenced by the dominant loess. In the Mongolian Plateau, Aeolian Sand frequently forms miles of sand waves, or dunes. In places in North China, loess forms thick layers of more than 100 m as already mentioned.

In the table-land of southwestern Manchoukuo, Shantung hill-land, and the Liaotung Peninsula, aqueous rocks, such as conglomerate, tuff, and sandstone, predominate, while hills of gneiss, porphyrite, and basalt lie scattered about. Here Aeolian Sand is rarely found, although a thin layer of loess may be seen on a hill-side which, owing to the prevalent direction of the wind, is usually on its eastern side. Thus soil, consisting mainly of the weathered products of these rocks and loess, is on the whole of medium richness. Seeing that in East Manchoukuo there are mountains of gneiss, granite, slate, and quartzite, judging from these rocks, the soil is equal to or somewhat inferior in character to that of those just mentioned. Since these conclusions are based on the rocks alone, obviously many other factors combine to determine the character of a soil.

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(1) Tokyo Geographical Society: Geological Atlas of Eastern Asia. (1929).

(G) Physical nature of the soil

In studying the nature of soil, it will be convenient to consider them from two aspects, the physical and the chemical. The former deals with the size, color, shape, and the arrangement of the soil particles, their water holding and absorptive powers. The latter concerns chiefly the nature of their constituent chemical elements, particularly their nutritious properties and soil acidity.

(1) **Soil texture and structure.**—Soils differ considerably in the relative fineness or coarseness of the particles of which they are composed (cf Fig. 26). Texture is that property which has to do with the relative proportions of particles of diffenrent sizes. According to the classification of the Agricultural Society of Japan(1), soils may be divided into five classes. Besides this, we have various other classifications which, however, are substantially the same.

In analysing the composition of the soil, the writer availed himself of the method of determination used by the Agricultural Society of Japan, with his own modifications of the apparatus.(2)

According to C. WIEGNER (1921), Fine Soil, whose individual grain is 2–20 μ in diameter, when piled up densely, keeps fine roots of *Graminae* from going into the ground. Fine Soil, whose grain is 20–200 μ in diameter, has strong capillary attraction, good water-holding power, and permeation, besides being easy to plough. Although it does not hinder air and heat from penetrating the soil, such Fine Soil as that just mentioned, alone by itself, is inevitably inferior in its chemical components, as will be explained later.

The chief physical properties of Clay (less than 10 μ) are a high water-holding power, high plasticity or stickiness, that of swelling when moist and of shrinking when dry, often accompanied by soil cracking. In fact, most of the colloidal properties of the soil are due to the clay particles and decom-

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(1) Report of the Agricultural Society of Japan, No. 284 (1926).

The classification now generally used in Japan is as follows:

Fraction		Diameter limits of particles
Gravel & Debris		More than 2 mm
Sand	Coarse Sand	2–0.25 mm
	Fine Sand	0.25–0.05 mm
Fine Soil	Silt	0.05–0.01 mm
	Clay	Less than 0.01 mm

Soil Class and Clay fraction in Fine Soil:

Soil class	Clay in Fine Soil
Sand	Less than 12.5%
Sandy Loam	12.5–25%
Loam	25–37.5%
Clayey Loam	37.5–50%
Clay	More than 50%

(2) TAKAHASI, M.: An ecological study of vegetation in the province of Jehol, Manchoukuo. Rep. First. Sci. Exped. Manch. sect., IV. P. III (1936) 8, Fig. 38.

posed organic matter. The inorganic soil colloids are complex aluminosilicates, resulting largely from the partial weathering of feldspars and other primary minerals. The nature and amount of soil colloids determine more than any other constituent the character of the soil. Coarse Sand of grains, 200 μ–2 mm in diameter, has only weak capillary attraction and small water holding power, with the result that soil rich in this component easily dries and is therefore unsuited for plant growth. Coarse Sand, however, has an important effect in counteracting certain unfavourable properties of Clay.

The relative amounts of these different grades of particles in a soil determine its texture. The coarse soil materials, consisting mainly of quartz or shattered rock fragments, represent the main body of the soil. Only the finer particles, the main products of weathering and decomposition, are very active in plant nutrition.

Many of the properties of a soil, such as content of air and water, depend upon the size of the soil particles rather than on their compositions. Soil texture not only exerts an important effect on the water relations but also upon aeration, as well as the supply of nutrients. With respect to texture, soils may be grouped into a number of classes, such as Sand, Sandy Loam, Clayey Loam, and Clay. Each is determined by the proportion of Silt, Clay, and Sand that it contains (cf the foot note of P. 511).

In addition to these, the nature of the soil depends also on the way in which the soil particles have accumulated, namely, soil structure. Soils of single-grain structure like Sand, where the particles function more or less separately, are fairly simple. They occur where there are insufficient cementing colloids to bind the particles together. Sandy soils tend to be dry, loose, and poor in soluble substances.

A very complex structure is represented in Clay where the soil granules or crumbs are composed of many particles bound together by colloidal material. Because of the excess of fine particles, the size of the interstices or pores is so small that neither water nor air can move freely.

Rich Loam usually serves as an example of a soil with excellent structure. In nature, good soil structure is maintained by alternate wetting and drying, by freezing and thawing, by the action of organic matter and lime, and by the mechanical action of plants and burrowing animals. A poor structure is produced by the puddling action of rain on bare soil surfaces, poor drainage, alkali, etc.

Humus has a very important effect in lightening a heavy soil and binding

Fig. 23. *Pinus tabulaeformis*—Sociation comprising some *Quercus mongolica* on Terra rossa in Kwantung Cape (face P. 505).
(M. TAKAHASI)

Fig. 25. A kind of "soil-polygons" or "structured soil" which may be seen in the arctic or alpine region (face P. 508).
(M. TAKAHASI)

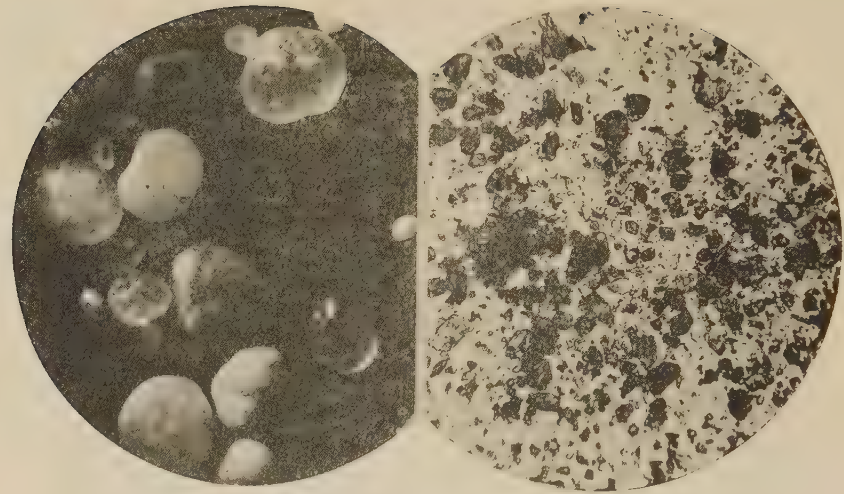

Fig. 26. Ball-like sand grains of a dune (the right) and angular particles of a loess (the left) under the microscope (face P. 511).

(M. TAKAHASI)

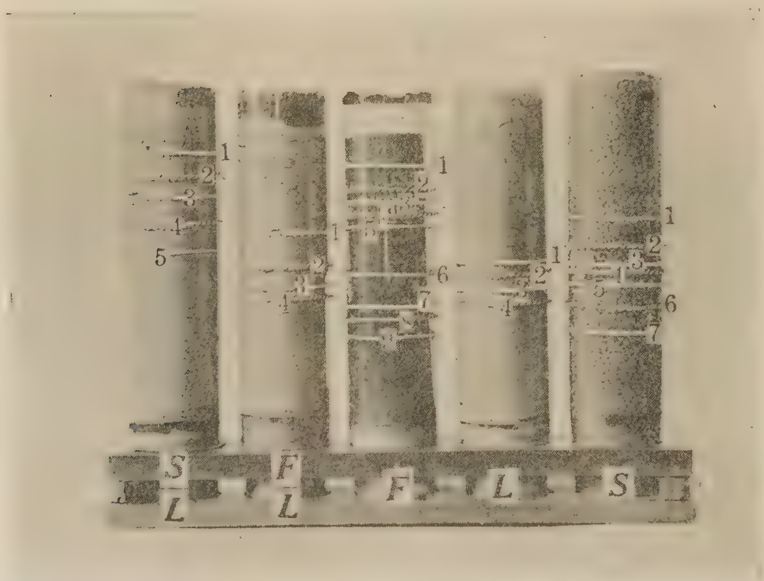

Fig. 27. Bottom-sealed glass cylinders packed with various soil samples (face P. 518).

$\frac{S}{L}$...... Loess with Sand layer (about 0.5 cm) above.

$\frac{F}{L}$...... Loess with humus layer (abont 0.5 cm) above.

F ...... Humus soil. *L*...... Loessial soil. *S*...... Sand.

(M. TAKAHASI)

a loose one, thus promoting good soil structure. Clay soils are usually improved in structure by the addition of lime, which flocculates the particles into large crumbs.

The soil is filled with pores and old root channels, the humus from decaying vegetation helps soil particles to cement into aggregates and thus lightens and enriches it. Soil structure affects the movement and storage of water in the soil and consequently soil aeration. Besides, water content and aeration, as well as compactness of soil, all profoundly influence root development.

Of the soils in the regions concerned, comparatively few have such complex structure. In the Mongolian Plateau and in the western Manchurian Plain, it arises from excessive Sand or Sandy Loam, and in North China, from the dominance of loess, but in the north or northeastern regions there is much Loam land holding considerable humus, so that one finds fairly good soils having a complex structure. Judging from these physical aspects alone, the last mentioned regions would appear to be the most ideal places for cultivation in the present regions under consideration.

(2) **Soil water.** — Since the water in soils, by profoundly influencing the form and structure of a plant, is closely associated with the wellbeing of the vegetation of a region, an intimate knowledge of these relations of water to other odjects is fundamental to the understanding of plant behavior and distribution of vegetation. Usually, the water content is expressed in percentage of dry weight of soil.

(a) **Water-retaining capacity.** The total amount of water that is held against the downward pull of capillarity and the force of gravity, and which does not drain through the soil, is termed the water-retaining capacity. In an arid or semi-arid region like the greater part of the regions concerned, the water-retaining capacity of the soil is of utmost importance, more so than any other soil attribute, and seeing that in any dry region, water is the decisive factor in vegetation, it behoves us to take into consideration the water-retaining and water-releasing properties of the various soils. Annexed is a Table of these capacities of certain soils.

As the results tabulated below, the water-retaining capacity is considerably plentiful in the forest soil rich in humus, next the Clay and third the Loam. The Sandy Loam is fairly good, but the capacity of the Sand greatly diminishes. The Sand and Silt particles retain water only on their surfaces. On the contrary, the particles of the colloidal constituents, like those of many

Table 3. Water-retaining capacity and effect on vegetation in dry season.

(i) This value is almost the same as when the "Soil point" is immersed in water.
(ii) According to LIVINGSTON and OHGA,[1] when the water supplying power is 0.3 gr/hour, the growth of even such a hardy plant as *Zoisia pungens* WILLD, which can stand considerable dryness, is checked.
(iii) This shows the largest variation of all soils.

Soil and its general water-retaining capacity	When water-retaining cacacity is —	Absorbing power at "Soil point"	Effect on vegetation in dry season
Humus (90–11%)	90%	3 gr/hour[i]	No great effect on plant growth
Clay (10–30%)	30%	1.77 gr/hour[ii]	Fairly marked
	20%	0.3 gr/hour	
Sandy Loam (0.88–19.6%)	19.6%	1.87 gr/hour	Retards too much the growth of plants
	8.81%	1.116 gr/hour	
Sand (2.8–9.2%)[iii]	9.2%	1.58 gr/hour	Very marked
	3.07%	0.074 gr/hour	

other colloidal systems, retain water by imbibition. Besides, by the amount of these colloidal constituents and expansible organic matters, the water-retaining capacity of the soil is determined by a number of factors, the most important of which are the total surface of soil grains, soil texture and soil structure. The smaller the particles of a soil the more film surface it will present for the retention of water.

When the sand particles are loosely cemented together by humus, percolation is diminished and the water-retaining capacity increased. On the other hand, minute clay particles are enclosed in aggregates by the colloidal film of humus. This results in increased percolation and a decrease in the aggregate soil surface for retaining water by capillarity.

In the presence of an excess of univalent cations, like in the case of Saline or Alkaline Soils, a greater proportions of the clay fraction of these soils disperse into its ultimate particles, and the soil has a single grain structure. On the other hand calcium soils, soils with a high content of calcium

(1) LIVINGSTON, B. E. and I. OHGA,: The summer march of soil moisture condition as determined by the porous porcelain soil point. Ecology, 7 (1926) 427.

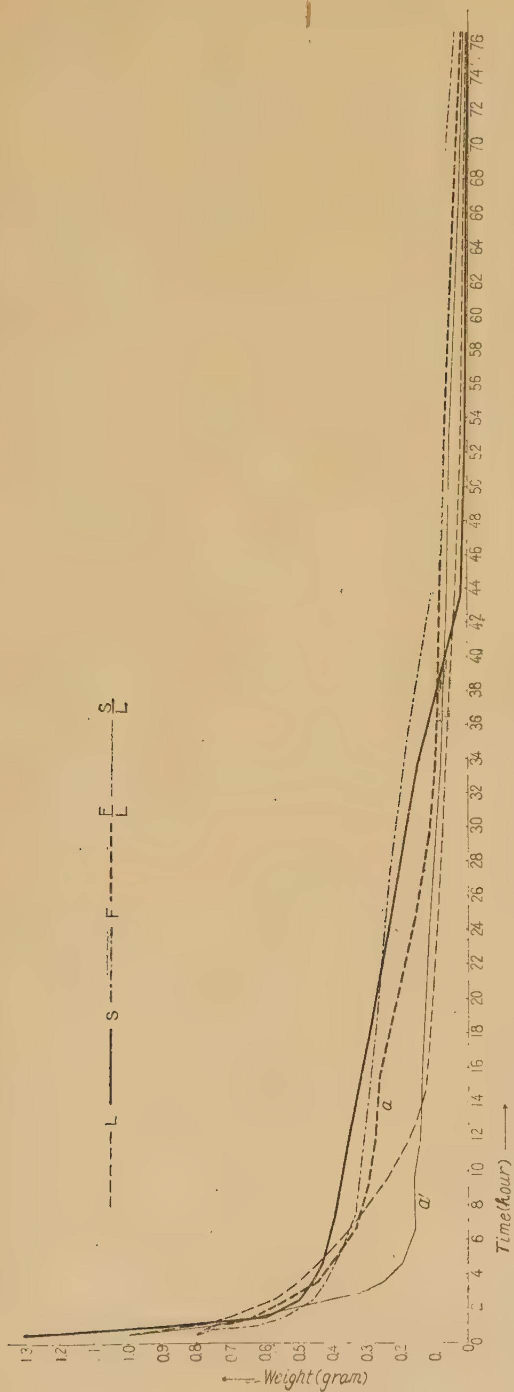

Fig. 28. Drying curve of the soil samples mentioned in Fig. 27, under the condition of 40° C and 10% relative humidity. (M. TAKAHASI)

(a bivalent cation), develop a good crumb structure and the crumbs are more stable than those often developed in acid soils.

(b) **Movement of soil water.** The distance to which water rises in the soil column is 35 cm in Coarse Sand, 70 cm in Fine Sand, and 80 cm in heavy Loam.(1) Generally speaking the capillary rise takes place most slowly, but to the greatest height in clay soils, and most rapidly but to lesser heights in sandy soils, loam soils occupying an intermediate position. Fine soil particles and colloidal matter greatly impede water movement in soils. When irrigation water is applied to a dry soil and equilibrium of soil moistures is reached, there is a fairly sharp transition from moist to dry soil.

For many years an important rôle was ascribed to the capillary rise of the water in maintaining the similar moisture conditions within soils. Recent investigations have shown, however, that the

(1) JEFFS, R. E.: The elongation of root hair as affected by light and temperature. Amer. Jour. Bot., **12** (1925) 577–606.

importance of this source of water in soils has been over-emphasized.

Cases are on record in dry climates where a moist layer of soil, due to excessive seasonal precipitation, has remained moist for many months with layers of dry soil both above and underneath it. In desert soils, movement of water at low percentages is almost nil.(1) Russian investigators have shown that where water has percolated below 30 to 45 cm depth in Clay, it never comes to the surface again except through absorption by roots. Even during seasons of extreme drought, uncropped soils lose but little moisture from their lower depths except as diffusion upward or downward as water vapours resulting from high soil temperatures. The surface a few centimeters thick may dry out, the depth varying with the type of soil, but capillary rise is impossible and continued loss of water from the surface cannot occur. This agrees with the writer's experiment.(2)

In his experiment he set five bottom-sealed glass cylinders, 20 cm long and 4.5 cm in diameter (cf Fig. 27), packed with different kinds of soil samples that have absorbed distilled water amounting to the respective water-retaining capacity, in a dry-chamber of constant temperature and humidity (at 40° C and 10% in relative humidity) and found that after the surfaces (a few cm thick) dry out and capillary rise is stunded, any continued loss of water from the surfaces of soil columns cannot or can scarcely occur, especially in the case of Sand. The decreasing rate of compound water from these five cylinders ($\frac{S}{L}$, $\frac{F}{L}$, F, L, and S, of which have already been touched in Fig. 27) will be understood from the drying curve of Fig. 28, the successive surface drying, which is recognized by the change in the soil color, is marked at the same time by the numbers on each cylinder. From this experiment, the conclusion is that little water is lost directly by evaporation from the surface of the sandy soil, and that, in general, the crop growth is much less luxuriant on the soil of this kind owing entirely to its decreased fertility.

(c) **Wilting coefficient.** If a rooted plant is allowed to wilt and die, examination of the soil shows that some water still remains. The water retained in the soil at the time of permanent wilting, which is not available

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(1) SHREVE, F. and W. V. TURNAGE,: The establishment of moisture equilibrium in soil. Soil Science, 41 (1936) 351–355.

(2) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the view point of ecology (Japanese). Geography, 8 (1940) 591–594.

for plants is usually but a small part of the water commonly present. The wilting coefficient is defined as the percentage water content of a soil after the plant or plants growing in it have just reached the condition of permanent wilting. In general this quantity seems to be controlled almost entirely by soil conditions and is only slightly influenced by the species of plant used,(1) or by the climatic conditions to which that plant is exposed.(2) The amount of this water is especially small in Coarse Sand, sometimes less than 1 per cent. In Silt or Clay, it may amount to 20 per cent and more. Unless the soil is quite moist and the water films relatively thick, capillary movement is very slow, and when the root hairs exhaust the water from the soil particles with which they are in contact, the plant wilts.

(d) **Soil drought and drought resistance.** Usually, soil drought conditions are accompanied by atmospheric conditions, such as hich temperature, low humidity, and often relatively high wind velocities, all of which favour high transpiration rates. Such "atmospheric drought" is not only the usual accompaniment of "soil drought", but sometimes occurs without any soil-water deficiency.

At any rate, plants of xeric habitats have been classified(3) as (1) ephemerals (drought-escaping plants), (2) succulents and xerophytes with reservoirs, (3) pseudo-xerophytes (ground-water plants and resemblance), and (4) euxerophytes (drought-enduring plants).

The ephemerals, which constitute a prominent feature of the vegetation of all semi-arid regions, are annuals adapted to such a short growing season that they are able to complete their life cycle from germination to maturing seed during but a brief period of water supply.

The second group resist drought by storing up a supply of water for use when none can be had from the soil. By means of this stored water, they may continue to grow for long periods, often flowering and ripening seed. Here belong the succulents, such as *Cacti* and *Agave* and other species with fleshy stems or leaves or roots. The peculiarities of assimilation and transpiration of *Cacti*, and similar succulents, are characteristics not possessed by other types of desert plants. The *Cacti* are further distinguished from other

(1) BRIGGS, L. J. and H. L. SHANTZ,: The relative wilting coefficients for different plants. Bot. Gaz., **53** (1912) 229-235.

(2) CALDWELL, J. S.: The relation of environmental conditions to the phenomenon of permanent wilting in plants. Physiol. Res., **1** (1913) 1-56.

(3) The writer's classification is somewhat different from other investigators.

xerophytes; they resemble epiphytes owing to their low osmotic pressure and to their sparse and superficial root systems. Notwithstanding their great economy in the expenditure of water, *Cacti* can not thrive in the Gobi Desert, where the temperature in winter falls below freezing point, resulting in lethal temperature. The other species of this group, however, are non-succulent plants, with ample reservoirs for water in their stems or underground organs.

In the third group, the absorbing root systems are usually developed to a considerable extent, accompanied by a decrease of transpiring surface. In the absence of subsoil water, however, even great development of the root system is unable always to provide the plant with sufficient water. These plants sometimes pass the driest part of the year in a state somewhat resembling anabiosis. In a semi-cold desert, such as in the driest part of Gobi, many plants have two resting periods. During the winter rest all the aerial organgs dry up, but in the summer resting period only growth ceases, although some of the leaves are desiccated.

The fourth group of plants, which grow but little in a single season, are usually small and widely spaced. When soil moisture is reduced below that available for growth, the leaves wilt or dry in places or may drop off entirely. These plants are able to endure these drought conditions, which are physiologically equivalent to permanent wilting, for months at a time, without suffering irrecoverable injury, after which they rapidly start growing with rainfall.

None of the explanations of the drought resistance of these drought-enduring plants from a purely morphological basis have proved adequate, although certain structural features of the plants undoubtedly aid survival in dry habitats. Recent investigations have clearly shown that one of the basic factors in the drought resistance of plants is the ability of the cells to endure desiccation without suffering any irreparable damage. The density of cell-sap of any species usually shows variations corresponding to the degree of aridity of the habitat, the highest osmotic pressures, except in succulents, usually being found in more drought-enduring species. The chief importance of high osmotic pressures in desert plants is believed to be during the period of wilting, when there is real danger of excessive water loss. High osmotic pressure causes considerable tension of the cell walls through increased turgor, thus preventing visible wilting for a long time, even though the water deficit continues to increase. This delayed loss of turgor enables the plant to con-

tinue photosynthesis for a longer period. At any rate, the xeric species or varieties of plants are the characteristic plants of deserts, to which last, however, they are by no means restricted; they are important plants in dry-farming areas, such as North China and southern Mongolia Regions.

Amongst these desert and semi-desert plants, succulents are not always abundant. It is true that in the American deserts they often form a striking feature of the vegetation, but in the Gobi Desert and its surroundung semi-arid regions, true succulents are very rare. Here dry, hard-leaved plants that belong to the third group are dominant, although sometimes they have more or less fleshy leaves. This succulence is chiefly the result of excessive salts in the soil, which condition some workers recognize as a physiological drought.

(3) **Soil air.**—Air, as well as water, fill the pore spaces of a soil. The pore space increases with fineness of texture, degree of granulation, and abundance of organic matter. Thus, the total pore space of a sandy soil may be only 30 per cent of its volume, that of Clayey Loam 45 per cent, but a heavy Clay may have 50 per cent. The pore space is increased by the addition of organic matter; in grassland soil, it is frequently as much as 60 per cent.

The relative proportions of water and air present in any given soil vary depending upon the water content of the soil. Many plants thrive best in soil that contains approximately 40 to 50 per cent of its maximum water-retaining capacity. The rest of the interstices, about 10 to 20 per cent of the valume of a soil, is filled with air. Water-soaked soils have no air except that dissolved in the water, but certain plants, such as *Salix brachypoda* KOM. and *Salix myrtilloides* L. in the marshy places of northern Manchoukuo and East Siberia, thrive well even under this condition.

Streaming of air into or out of the soil may be due to changes in temperature or variations in atmospheric pressure, causing expansion and contraction of the soil air, which last is also displaced by the entrance of rain water.

The soil air is not static either in volume or composition, but is constantly undergoing change. Soil air differs somewhat in composition from the ordinary atmosphere. For example, under grassland or forest soil, air often contains much carbon dioxide, sometimes amounting to 5 per cent and even more; such values are far in excess of the average value of 0.03 per cent for the air. The accumulation of carbon dioxide in soils is due more to the metabolic activities of micro-organisms than to respiration of soil warms and the underground portions of vascular plants. Except in very dry soils the soil

atmosphere is usually saturated or nearly so with water-vapour. In the soil, oxygen is important in the process of breaking down insoluble minerals or disintegrating plant and animal remains into soluble forms, and in consequence enrich the soil.

(H) **Chemical nature of the soil**

The writer collected hundreds of samples of typical soils throughout the regions concerned, except in Russian territory, for various tests and analyses at the laboratory in the Botanical Institute of the Imperial University, Tokyo.

Moreover, during his journeys throughout these regions, he made good use of his time in observing soil prophiles and determining by the colorimetric method the acidities of soils, as well of the waters of rivers, ponds, springs, and wells.

(1) **Soil acidity.**—It is usual to determine the acidities of the soil within twenty-four hours of collection, for the reason that lapse of much time is supposed to cause irreversible changes in the soil, in consequence of which the soil does not recover its former acidity by the mere addition of water later.

This precaution, although necessary in the case of soil in a comparatively damp region like Japan proper, is needless in such arid and semi-arid regions concerned, except northern Great Khingan Mountains (大興安嶺山脈), East Manchoukuo, and Russian terriotory. Errors, if any, would probably at any rate be within the limits of that by the colorimetric method (or indicator method). Although the writer tested the collected soils on the spot, and again after intervals of from one to four months at the laboratory, both with the same method, the results were practically identical. Needless to say, this result is as it should be by the colorimetric method, but if the tests had been made by the electrometric method (or Quinhydron method), some differences would probably have been observed.

(a) **Causes of acidity.** Although acidity of soil naturally arises from various causes, it is due primarily to the leaching of the soluble basic salts, especially calcium carbonate. In a damp and hot region, chemical weathering or decomposition predominates, whereas in a dry and cold region, on the contrary, physical weathering or disintegration prevails. These two conditions are of course found both singly and independently of each other, but frequently with the one merging into the other. In these weathering courses of rocks, calcium carbonate is always formed or released, except in those very rare

cases where the original rocks contain no compounds of calcium. Although magnesium carbonate is formed in the same manner, it is usually less abundant. When calcium carbonate is leached from the soils, the last named become strongly acid; and these soils, having a very low pH, are also likely to be low in other mineral plant foods such as phosphate, potash, and nitrogen. In a very general way, then, the degree of leaching, as indicated by the pH and the lime content, partly indicates the natural fertility of the soil, but it cannot serve as a sure guide to its productivity under the influence of efficient agricultural methods.

On the other hand, even weathering of the same rock, instead of always resulting in the same soil, produces various soils according to the influence of topography and climate. Thus climatic conditions during weathering also affect the pH of the produced soil. Where the soil is rich in moisture, the soluble basic salts are apt to run off into the ground. These carbonates which, in the presence of acidulated water, form the soluble bicarbonates, are carried downward in the soil. When the soil becomes drier, as the result of absorption by roots, they are deposited as insoluble carbonate, whence surface soils are usually more acid than subsoils.

For the same reason, hilltops, ridges, and upland of a rolling topography may be acidic in reaction, while the lower slopes and level lands may be neutral.(1) Generally speaking, however, soils of high altitudes are more acidic than those of lower altitudes.(2)

Soils of organic origin most generally owe their acidity to accumulations of humus under conditions of poor aeration, but sometimes to liberation of inorganic acids from the mineral constituents of the soils. Decomposition of organic matter by fungi leads to the production of organic acids and relatively soluble substances, and to the reduction and solubility of iron.

It is believed that both the inorganic and organic colloids of the soil adsorb various substances. Probably, by a combination of physical and chemical processes, the molecules, atoms, or ions are adsorbed on the surfaces of the colloidal particles, H-ions being among the substances adsorbed. A neutral salt in the soil, for example, calcium chloride, may replace some of the adsorbed H-ions, and the latter, going into the soil solution, increases acidity. The base

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(1) SALISBURY, E. J.: The soil of Blakeney Point—a study of soil reaction and succession in relation to the plant covering. Ann. Bot., **36** (1922) 391–431.

(2) CAIN, S. A.: Ecological studies of the vegetation of the Great Smoky Mountains of North Carolina and Tennessee. Bot. Gaz., **91** (1931) 22–41.

exchange, moreover, that has resulted from the double decomposition is also an important chemical reaction occurring in both the inorganic and organic colloids of soil.(1) The colloidal nucleus or micella, which is negatively charged, has the power to adsorb cations of calcium, magnesium, potassium, sodium hydrogen, and other elements. Soil colloids are of three principal types which are called the hydrogen, the sodium, and the calcium colloids, all of which are more or less saturated with adsorbed positively charged hydrogen, sodium, or calcium ions, respectively. In the absence of calcium, magnesium, or other flocculating electrolytes, the hydrogen colloid is acid and easily dispersed into a colloidal suspension which may be readily leached from the surface soil. Although the sodium colloid is highly alkaline and is even more easily dispersed and leached, the calcium colloid, which is mildly alkaline, remains in a flocculated condition.(2)

The strength of an acid solution does not depend on the total quantity of acid present in it, but rather upon the H-ion concentration. Since it is the ionized hydrogen alone that is responsible for the acidity of a solution at any given moment, it is clear that the H-ion concentration of a soil solution is a valuable criterion for biochemical purposes.

(b) **Effects upon plants.** From its nature, soil acidity is intimately related to the germination and growth of plants.(3) It may always affect plant growth by checking the work of nitrifying bacteria and all forms of nitrogen-fixing bacteria. Earthworms are sensitive to soil acidity, their absence and general decrease in soil organisms preventing the normal decay of humus and promoting the accumulation of carbon dioxide and the resulting toxic organic substances. Acidity also markedly effects the availability of soil salts, the solubility of phosphate, calcium, magnesium, iron, aluminium, and manganese being markedly influenced by it. The harmful effects of acidity may be due to increased concentration of aluminium(4) or manganese.(5) In acid soil,

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(1) WHERRY, E. T.: Soil acidity and a field method for its measurement. Ecology, **1** (1920) 160–173.

(2) KELLOGG, C. E.: The place of soil in biological complex. Science, **39** (1934) 46–51.

(3) KURZ, H.: Hydrogen ion concentration in relation to ecological factors. Bot. Gaz., **76** (1923) 1–29.

(4) WRIGHT, K. E.: Effects of phosphorus and lime in reducing aluminum toxicity of acid soils. Plant Physiol., **12** (1937) 173–181.

(5) BORTNER, C. E.: Toxicity of mangenese to Turkish tobacco in acid Kentucky soils. Soil Science, **39** (1935) 15–33.

the crumb or flocculated structure of clay may be destroyed and the soil found to be in poor physical condition, as a consequence of which the water content is increased and aeration diminished. Besides, plants generally need lime, which occurs in too small amounts in acid soil.

For these reasons, it must be admitted that variations in pH do cause changes in growing plants, although not all plants are affected in the same way. While general plants are found in soils with the value of pH 6 to 7 most suited to them, the experiments of RUSSEL[1] and ARRHENIUS[2] show that even these plants can grow fairly well in soil having higher pH values than what is supposed to suit them best.

Some species of plants have only one suitable value of pH, while others have two values, the latter having a wider sphere of existence than the former. E. J. SALISBURG, who tested the pH of the forest soil of *Quercus dentata* THUMB. and *Fagus sylvatica* L., showed that both have two suitable values of pH, which fact was generalized as follows:—Plants of this kind have the power to form different communities, and that a plant with only one suitable pH is able to form only one sort of community, a sort of generalizations which the writer is unable to endorse.

For purposes of reference, the writer will now classify the plant, theoretically, with reference to the influence of the pH on it.

- Acidophils; grow on soil showing pH values less than 6.9
  - Strong Acidophils; grow on soils having pH less than 4.4
  - Moderate Acidophils; grow on soils having pH 4.5–5.5
  - Slight Acidophils; grow on soils having pH 5.6–6.9.
- Neutrophils; grow on soil showing pH value 7.
- Basophils; grow on soil showing pH values more than 7.1
  - Slight Basophils; grow on soils having pH 7.1–7.5
  - Moderate Basophils; grow on soils having pH 7.6–8.1
  - Strong Basophils; grow on soils having pH more than 8.2.
- Indifferent; capable of existing whether in acid or basic soil.

(1) RUSSEL, E. T.: Soil condition and plant growth. (1923) 491.

(2) ARRHENIUS, O.: Kalkfrage, Bodenreaktion und Pflanzenwachstum. Akad. Verlag, Leipzig, (1926).

The foregoing values differ somewhat from ordinary values, the writer having modified them for the following reasons: pH 4.4 and 8.2 are the maximum and the minimum limits for existence of the bulk of forest trees except some extreme cases, while pH from 5.6 to 7.5 is the most suitable limit for the existence of common cultivated plants. It seems that soil with pH exceeding 7.5 or less than 5.5 increases the abnormality of growing plants, so that communities developed on soils with an approximately neutral reaction are usually aggregates of the largest number of species.

In natural communities, the great grassland areas are found on nearly neutral to moderately alkaline soils. Moderately or slightly acid soil (pH 5.5 to 6.9), characterized by relatively great activity of micro-organisms, high availability of mineral nutrients, good structure and aeration, are very favourable to tree growth. It is on such soils that we find the majority of the great deciduous forests.(1) Within the range of pH 4.5–5.5, most coniferous trees and many northern deciduous trees are found. In northern regions, soils with pH 3.7 to 4.5 frequently support stands of *Larix Gmelini* LEDEB. or *Larix olgensis* HENRY. Soils more acid than pH 3.7 normally are not forested, but clothed with heaths of low shrubs, lichens, etc., or with bog thickets. Certain species of low shrubs, such as *Vaccinium* and *Rhododendron*, grow only in these acid soils. The limits of pH value of a soil within which a forest could exist is 8–8.2, a forest consisting solely of *Populus*. In soil of pH more than 8.5, only two species, *Glaux maritima* L. and *Cyperus pannonicus* JACQUIU, can thrive, the above-mentioned soils of pH 9 and 8.7 being quite sterile. From the viewpoint of pH values, therefore, vegetation in the northern part seems to be classifiable into medium and strong Basophil. In this region, the value of pH shows considerable local changes owing to accumulations of salts being scattered here and there, the remarkable feature being the concentric vegetation, or vegetation in concentric circles with a salt accumulation as a center.

Among cultivated plants, buckwheat, potatoes, and oats are fairly tolerant to strong acidity, but tobacco, peanuts, and onions are injured by moderately acid soils.

Unless acidity is quite marked, its effects are usually overshadowed by the water and air relations. In bogs, aeration is the dominant factor and acidity is concomitant. A definite correlation between acidity and the presence

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(1) WILDE, S. A.: Soil reaction in relation to forestry and its determination by simple tests. Jour. For., 32 (1934) 411–418.

of sphagnum has been established.(1) In nature, it is difficult to find marked changes in acidity without at the same time discovering great physical, chemical, and other differences in the environment.(2) Habitats with the same pH value but differing in other factors show corresponding differences in vegetation.

(c) **H-ion concentration and soil distribution.** The pH value map is very similar to the calcium carbonate map (cf Figs. 29 & 30). The greatest concentration of lime is in the young and imperfectly developed light and very light Chestmut Earths of loessial regions and in the deserts, where leaching is at a minimum. The very sandy and rocky parts of the desert, however, contain relatively little lime.

The high lime content of the deep loess deposits is due partly to the fact that the dusts of which they are composed were blown from calcareous deserts, and partly to weathering of some of the dust particles since their deposition.

The Gray-brown Podzolic Soils vary from strongly to moderately acid in reaction, and the Shantung Brownsoils have reactions varying from slightly acid to slightly alkaline, showing that acid leaching has had a comparatively mederate influence on them. The alkaline soils including saline and alkaline soils, have a high pH value because of the presence of "sodium clay" and, in some cases, of free sodium carbonate in them. This is because sodium clay comprises colloidal materials that have absorbed sodium from the saline solutions around them.

In the presence of water, these sodium clays hydrolize or form a little free sodium hydroxide which, as it is well known, is a very strong base and leads the soil to an alkaline reaction. If there is sodium carbonate in the soil it also hydrolizes to form sodium hydroxide. It will be of interest to note that the degree of leaching as expressed by the pH value and lime content is approximately the same for the Degraded Chernozems and the Shantung Brownsoils. It is probable, however, that the average pH value and lime content is slightly higher in the Shantung Brownsoils than in the Degraded Chernozems of the Manchurian Plain.

Figures 29 and 30 show the approximate distribution of soils having

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(1) KURZ, H.: Influence of sphagnum and other mosses on bog reactions. Ecology, **9** (1928) 56-69.

(2) IKENBERRY, G. J.: The relation of hydrogen-ion concentration to the growth and distribution of mosses. Amer. Jour. Bot., **23** (1936) 271-279.

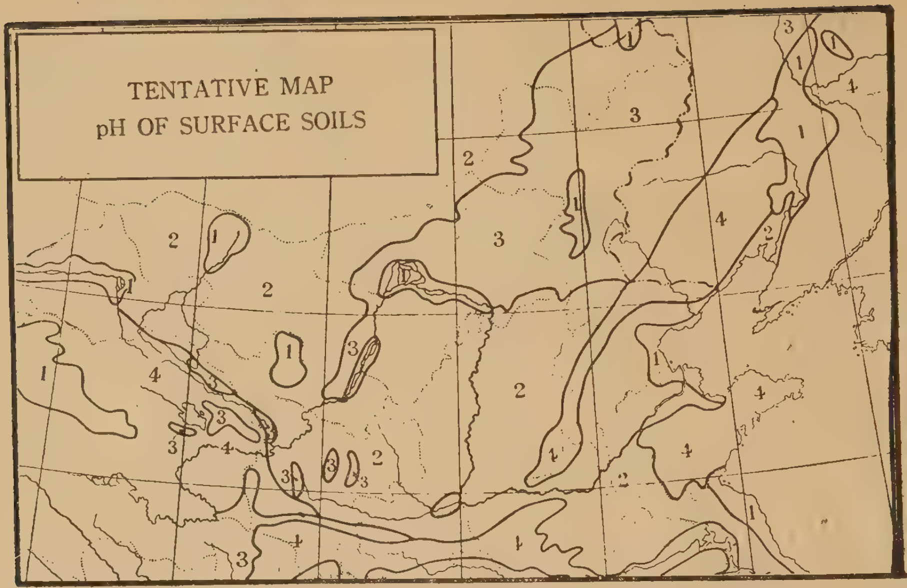

Fig. 29. The pH value map of the northern East-Asia.

1...... 8.6–9 or more 2...... 8.0–8.5
3...... 7.4–7.9 4...... 6.4–7.3 (after J. THORP)

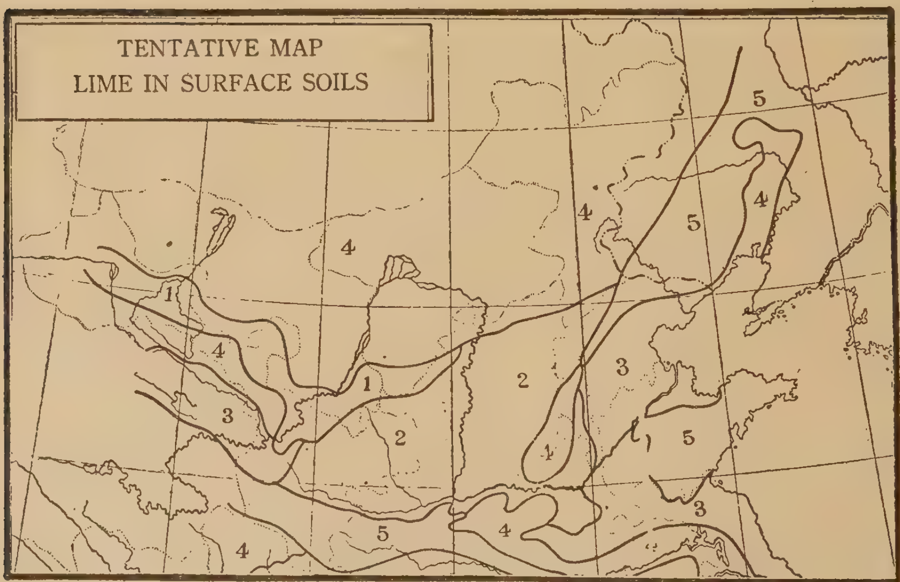

Fig. 30. The calcium carbonate map of the northern East-Asia.

1...... over 13% 2...... 6.6–13% 3...... 3.6–6.5%
4...... 0.5–3.5% 5...... 0.5 or less (after J. THORP)

approximately equal pH reactions and equal contents of lime. It will be seen at once that soils having a high pH value correspond closely to those containing free calcium carbonate. When we examine the map, we find calcium carbonate highly concentrated in the soils of semi-arid and arid regions while there is practically none in the humid temperate regions where the weathering is more rapid. The only possible explanation of this phenomenon is, as already mentioned, that leaching takes place much more rapidly in humid than in dry regions.

(2) **Chemical components.**—As the greater part of soils consist of inorganic matter, of which the main components are compounds of K_2O, Na_2O, CaO, Mg_2O, Fe_2O_3, Mn_3O_4, NH_3 and of SiO_2, SO_3, P_2O_5, CO_3, N_2O_5, Cl, in order to ascertain fully the chemical composition of the soils in the regions concerned, the writer made chemical analyses by methods of ordinary quantitative analysis, with however certain improvements of his own, particularly in the quantitative analysis of humus and in the estimation of potassium and sodium.

Judging from the chemical analysis, the northwestern Mongolia and its surrounding arid or semi-arid regions, compared with the southern or southeastern humid or semi-humid mountainous regions, are comparatively rich in the various salts except that of iron, but rather poor in nitrogen compounds and humus.

This, as already explained, is due to the fact that in the northwestern arid or semi-arid regions, rock disintegration is rapid through deficient moisture; while there is not much decomposition, and the salts are rarely washed away by rain. In the southern or southeastern mountainous regions, on the contrary, owing to the frequent summer rains, decomposition exceeds that in the northwest, while in consequence of the many slopes, the salts are easily washed away by rain.

In considering next the relationship between the chemical nature of soil and vegetation, we have the well known fact that, since plants, besides depending on carbonic anhydride in the air as the only source of carbon, take all the other nourishing substances from the soil, the amount of salts contained in the soil necessarily influences their growth. But the nourishing substances for plants, especially their indispensable components, such as C, O_2, H_2, N, S, P, K, Ca, Fe, and Mg, are contained everywhere in the earth's crust as various compounds, as that ordinarily serious injuries to plant growth rarely occurs, although in some regions they happen quite frequently.

From the ecological point of view, the writer classifies these injurious results as follows:

Injurious results from lack of certain necessary components.

(i) Lands in which the salts flow off through rigorous washing action; for example, naked slopes, dry river-beds, and regions of much rain and excessive drainage.

(ii) Shortage of N, Ca, P, and K in waste land resulting from non-manured cultivation.

(iii) In the sandy soils of dunes and deserts, organic substances are scanty and the propagation of bacteria unfavourable, so that the soil lacks N.

Injurious results from excess of certain components.

(i) Harmful effects of NaCl, Na_2CO_3, and Na_2SO_4 in Alkali Soils (generic term for Saline and Alkaline Soils), such as the seasides, near salt-lakes, and of Alkali Soils resulting from various other origins.

(ii) Acid soil resulting from humus, in which the alumina sometimes amounts to injurious excess.(1)

(iii) Harmful effects of excessive calcium content in soil of weathered limestone.

(iv) Effects of sulphuric and sulphurous acids in the vicinity of volcanoes and hot springs.

The parts played by these elements in plant metabolism are not so completely understood. Actually a very large proportion of the mineral elements in plants act in some other way than as material from which essential parts of plant cells—such as the sulfur in proteins, or the magnesium in chlorophyll—are constructed, or else are of no apparent consequence in the metabolism of the plant whatsoever. Details of these relationships are as follows:—

(a) **Calcium.** Calcium, besides being indispensable to plants as a nourishing substance, is also intimately related to the physical, chemical, and bacteriological characters of soil, that is, it works as a modifier of soil conditions. The main compounds of calcium in soil are the sulphate, carbonate, nitrate, phosphate, the double salt of calcium and silicic acid, the calcium salts of humic acids, etc. Of these salts, since calcium sulphate has low

(1) HOSONO, K.: Journal of Agriculture Study, **21** (1933) 411.

solubility in water, if its concentration in the soil were to increase, it would crystallize in white crystals with other salts. These crystals sometimes constitute the main components of White Alkali Soil, for example, in Formosa. In the soils of the regions under consideration, the quantity of calcium sulphate is not generally so great, however, these crystals are rarely found under the Red Clay of very arid parts.

A large proportion of the calcium in most plants is located in the leaves. This element apparently plays a manifold rôle in plant metabolism. For example, calcium ions have pronounced effects upon the permeability of the cytoplasmic membranes and upon the hydration of colloids. Calcium is of widespread occurrence in plants in the form of calcium soaps and is also of frequent occurrence in cells that of insoluble crystals of calcium oxalate or salts of other organic acids. So some investigators consider that calcium performs an important function in combining with the organic acids within the cells.

In many species, deficiency of calcium results in stunted root growth. The leaves become hard and stiff, often yellowish. There is also some evidence that insufficient supply of calcium interferes with the translocation of carbohydrates and the amino acids.

Certain species of plants have been grouped into calciphilous (calcicolous) and calciphobous (calcifugous) species according to whether they have an inclination to grow on limestone or on siliceous soils. But species may differ markedly in its relation to lime soils in different parts of its climatic range, being, for example, calcicolous in the colder, northern and higher localities, and more or less calcifugous in the warmer regions, all of which have to do with lower soil humidity, hence greater salt concentration in the warmer sites. Experiments have also shown that the calciphobous species, such as *Rumex acetosella* L., also flourish in soil rich in lime, provided the other soluble salts are not in excess. In Mongolia, it has been shown that, as a rule, the superficial horizons determine the species, especially annuals, whilst variations in the soil profile affect the heights of individual plants.

As to the quantity of calcium necessary for the soil from the agricultural point of view, opinions diverge, the question being still far from settled, but according to HOHL, when the percentage of calcium carbonate is less than 1, calcium fertilizers exercise marked effects.

(b) **Phosphorus.** In general, phoshorus, which is most abundant in young, meristematic cells, is utilized in considerable quantities in such growing parts

in the formation of nucleoproteins and other phosphorus-containing compounds. It is also used in considerable quantities during the period of maturation of fruits and seeds. Phosphates act as the co-enzyme of zymase and seem to exert an accelerating effect on other oxidizing and reducing enzymes. There is also some evidence that phosphorus is necessary for the hydrolytic transformations of carbohydrates in plants, particularly the change from starch to sugars.

Since deficiency of phosphorus interferes with the synthesis of lecithin and other phospholipids, and nucleic acids, it may interrupt normal cell division in meristematic tissues, the leaves changing to a dark green, often with enhanced anthocyanin development. Fruits are slow ripening and seeds are late maturing.

The quantity of phosphorus in the soil of the greater parts of the regions under consideration is generally larger than in that of Japan, Korea, or Formosa. The greater part of the phosphorus in the soil is in the form of either iron phosphate or aluminium phosphate combined with iron oxide or alumina. The relation between salts exists also between phosphoric acid and iron oxide, alumina, calcium, and magnesia.(1) LIEBSCHER has given the ratio of phosphoric acid to the combined quantity of iron oxide and alumina. This ratio and vegetation has the following relationship;

Ratio of phosphoric acid to combined irón oxide and alumina	Effect on vegatation
less than 40	very favourable
40–60	favourable
60–90	somewhat unfavourable
more than 90	unfavourable

The ratios of the soils in question on the whole belong to the second class (favourable).

(c) **Potassium.** Potassium is usually the most abundant univalent cation in plant cells, and it occurs in plants almost solely as soluble inorganic salts, however, its salts of organic acids are also found. It is an indispensable element and cannot be completely replaced even by such chemically similar

(1) Strongly calcareous soils sometimes contain a great abundance of phosphorus and nearly always they have a sufficient amount of this element for crops; but the phosphorus may be combined with the lime in such a form as to be only very slowly available to plants. In cases where phosphorus occurs abundantly in soils which are high in iron content it is also likely to be in an unavailable form because of the formation of insoluble iron-phosphate compounds.

elements as sodium or lithium. The young and active parts of plants, especially buds, young leaves, root tips, etc. are always rich in this element.

The exact rôle of potassium in plants is obscure. It appears, however, to be necessary for the normal maintenance of the following processes: (1) the synthesis of simple sugars and starch, (2) translocation of carbohydrates, (3) reduction of nitrates, (4) synthesis of proteins, particularly in meristems, and (5) normal cell division. It may exert many of its effects by influencing enzymatic activity. In the absence of this element the cells elongate, but do not divide.

Deficiency of this element results at first in the stunting of the plant as a whole. Leaves becom dull green, sometimes yellow and seeds often fail to mature; when they do are relatively small in size.

Potassium, although largely contained in silicates forming soil, for example, potass felspar, mica, etc., are mostly insoluble in water in the form of these salts. Potassium absorbed directly by plants through their roots is in the form of hydrosilicate and other soluble salts absorbed by the soil. The quantity of potassium in the soil in question is on the whole much larger than that of Japan proper and Formosa.

(d) **Nitrogen.** Although nitrogen is the substance most needed for plant growth, it is the one that is most liable to be scarce in the soil. Deficiency of nitrogen results in the stunting of the plant as a whole. Leaves are relatively small in growth and yellowish green in color, and often abundant anthocyanins in veins. Fruits are small when mature and seeds light in weight. The plants depend upon air, fertilizers, and other organic substances for the nitrogen needed. Of these sources, free nitrogen, which forms 79.04% of air, is utilized only by the *Leguminosae* and a certain species of *Betulaceae*, most plants taking it indirectly from reduced products in the soil merely by *Azotobacter* and other nitrogen-fixing bacteria. So nitrogenous compounds absorbed from the soil serve as the sole source of nitrogen for almost all green plants. Such plants can utilize four kinds of compounds as sources of nitrogen: (1) nitrates, (2) nitrites, (3) ammonium salts and (4) organic nitrogen compounds. Most plants absorb nitrogen in the form of nitrates. Nevertheless normally metabolizing plants usually contain only relatively small quantities of nitrate, because the nitrogen of nitrate ions is reduced to other forms almost as rapidly as it enters the plant.[1] Under certain

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(1) NIGHTINGALE, G. T.: The nitrogen nutrition of green plants. Bot. Rev. 3 (1937) 85–174.

conditions, however, plants accumulate relatively large quantities of nitrates in their tissues without any toxic effects.

When ammonium fertilizers are applied much to agricultural soils, nitrification usually occurs very effectively, resulting in rapid conversion of ammonium compounds to nitrates. In most cases the nitrogen in the soil is in the organic state, with the result that the quantity of organic matter in the soil is an indication of that of nitrogen in it. This fact holds true in the case in the regions where the quantity of nitrogen is large in the soil groups of Chernozems, Podzols, Bog Soils, Tundra Soils, and Dark colored Alpine Soils. From the viewpoint of soil grains, generally Clay and Loam have a larger amount of nitrogen than Sand.

(e) **Sodium.** Generally speaking, the sodium salts are absorbed less by soil than the potassium salts, and is more easily washed away by rain. But in such a dry region as Mongolia the salt, by remaining intact in the soil, acts injuriously to vegetation. Sodium salts exist in the soil mainly as chloride, carbonate, or bicarbonate, and with the drying of the soil, move upward and appear on the surface of the earth. Since the salt covers the surface of the soil particles, it occupies space among the soil grains and destroys the complex structure of soils. The salt, in all these ways, therefore, indirectly acts harmfully to plant growth, while at the same time, the ions of the salt injures in a direct way the roots of plants. Of all the sodium salt prevailing in nature, its carbonate is most injurious, followed by its chloride, and next its sulphate.

In some halophytes it is present in considerable amounts, most of it being dissolved in the cell sap in the form of sodium chloride. In part sodium can replace potassium as one of the essential elements, but no plant will survive in the total absence of potassium, even if sodium is available.

(f) **Aluminium.** This element is one of the most abundant of those present in the soil, although it occurs chiefly in insoluble forms. A larger proportion of soluble aluminium is generally present in relatively acid soil (below pH 5.0) than in soils of higher pH.

Aluminium is probably universally present in plants, although the amount in most species is very small. While this element is not considered to be one of the essential elements it is known to have a number of pronounced effects upon plants. The detrimental effect of soils with a pH of 5 or less upon the growth of some species is undoubtedly due, at least in part, to the toxic effect of the relatively high concentration of aluminium ions in such soils. The beneficial effect upon the growth of some species of adding lime or phosphates

to acid soils is at least partly due to a reduction in the solubility of the aluminium compounds present.(1)

(g) **Sulfur.** As a rule, this element seems to be fairly well distributed throughout the organs and tissues of plants. Sulfur is a constituent of the amino acid cystine, of glutathione, and of the mustard oil glycosides, such as sinigrin. Much of the sulfur, however, often remains in the inorganic form as sulfates.

Chlorophyll development is often retarded in sulfur-deficient plants. In many species the chlorosis on the leaves is observed first along the veins. The pale green color of such plants soon changes to a deep green when sulfur is applied. In legumes, abundant sulfur also favours root nodule development, while in some species, deficiency of this element has been reported to have a retarding effect on cell division and fruiting. At any rate, deficiency of this ion can readily be demonstrated in solution cultures. It is doubtful if this phenomenon occurs in natural soils, in general, sulfur occurs in soils in sufficient abundance to supply the needs of plants. On the other hand, excess of this element is often recognized in volcanic areas or hot sulfur springs the Solfataras, around which are found characteristic xerophyll vegetations.

(h) **Chlorine.** The presence of chlorine, which seemes to be universal in plants, is apparently almost wholly in the form of inorganic chlorides. This element is a constituent, however, of the molecules of anthocyanins. The expeimental results which have been obtained upon supplying chlorides to plants have varied greatly. In some species a definite beneficial effect has been noticed, while in others applications of chlorides have retarded plant growth, while in still others no apparent effect could be detected, which, obviously, is not convincing evidence that this element is essential for plants.

Plants indigenous to salt marshes and saline soils(2) can endure the presence of relatively large quantities of chlorides, usually sodium chloride, in the soil. Asparagus is an example of a crop plant which not only tolerates, but actually requires, treatment with sodium chloride for its best development.

(i) **Silicon.** This element comprises a very large proportion of the ash of some species, particularly of the aerial portions of members of the grass and *Equisetum* families. It is also fairly abundant in the bark of trees.

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(1) WRIGHT, K. E.: Effects of phosphorus and lime in reducing aluminium toxicity of acid soils. Plant Physiol., **12** (1937) 173–181.

(2) Detailed explanations will be found under Semi-cold Halophyte Formation.

Formerly it was believed that silicon was important in contributing to the stiffness of the straw in cereal crops, but more recent experiments do not support this view. Silicon appears, however, to have an important effect upon the phosphate metabolism of plants.

(j) **Iron, Magnesium, Manganese, Copper, Zinc and Boron.** Of the remainder of the elements to be discussed in this section, the following six are not generally considered very important, especially from the viewpoint of ecology, although some of them, in extremely low concentrations, exert marked effects on the development or metabolism of plants. The reason is that these elements usually occur in soils in sufficient abundance to supply the needs of plants, although occasional exceptions are met with.[1]

Iron.—This element is indispensable for the synthesis of chlorophyll in green plants,[2] deficiency of which results in the development of a characteristic chlorosis.[3] The condition of the iron in plant tissues is also often a factor determining its influence in chlorophyll synthesis. Deficiency of available iron in soils is seldom a limiting factor in plant development, although occasional exceptions are encountered. Even in the latter case, deficiency is usually due to the insolubility rather than to its actual absence.

Magnesium.—This element is the one and only mineral constituent of the chlorophyll molecule, although seeds are also relatively rich in this element. Magnesium is believed by some workers to be intimately related to oil formation and the synthesis of nucleoproteins in plant cells.

Manganese.—This element is, as a rule, most abundant in the physiologically active parts of plants. It is supposed to play a part in oxdation and reduction phenomena.[4] Manganese is also related in some way to chlorophyll synthesis, seeing that a deficiency of this element usually results in the development of a chlorotic condition in plants, which condition, however, differs from that due to iron or magnesium.

Copper.—This element is widely distributed in plants although it never constitutes a large proportion of the ash. According to many experimental

(1) BRENCHLEY, W. E.: The essential nature of certain minor elements for plant nutrition. Bot Rev., 2 (1936) 173–196.

(2) ROGERS, C. H. and J. W. SHIVE,: Factors affecting the distribution of iron in plants. Plant Physiol., 7 (1932) 227–252.

(3) BENNETT, J. P. and J. OSERKOWSKY,: Copper and iron in the tracheal sap of deciduous trees. Am. Jour. Bot., 20 (1933) 632–637.

(4) CLARK, N. A.: Manganese and the growth of Lemma. Plant Physiol., 8 (1933) 157–161.

results, copper can be shown at least to be essential for flax, tomato, sunflower, and barley plants by a solution culture technique.[1, 2] The productivity of peat soils in particular can usually be increased by applications of copper sulfate.

Zinc.—Observations are on record indicating that zinc, like copper, may have a beneficial effect upon plants under cultural conditions.[3]

Boron.—The exact rôle of this element in plants is unknown, but it is noteworthy that its absence usually affects the meristematic tissues, causing blackening and death or growth abnormalities.[4, 5, 6]

Except in very low concentrations these six elements are distinctly toxic to plants and the quantity of these elements required is, as would be expected, exceedingly minute.[7]

The writer has here enumerated the most important components, the excess or lack of which can easily be ascertained, but it is difficult to determine the exact extent to which the salt is in lack or excess, seeing that the amount of nourishing substance absorbed by plants differs with species, even the same species taking different amounts according to season.[8] Sometimes plants can compensate to some extent for the lack of salt with another salt that happens to be in excess, while some component, with its small amount of salts, is enough for other plants. It would thus seem an easy matter to ascertain the cause of the injury, whether it is due to lack or excess of salts, but owing to the complicated conditions involved, it is very difficult to determine the exact cause from which the harm results.

As the usual chemical analysis of a soil by means of boiling concentrated hydrochloric acid is merely a quantitative analysis of the soluble salts, the

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(1) LIPMAN, C. B. and G. MACKINNEY,: The essential nature of copper for higher green plants. Plant Physiol., **6** (1931) 593–599.

(2) SOMMER, A. L.: Copper as an essential for plant growth. Ibid., **6** (1931) 339–345.

(3) ——, and C. B. LIPMAN,: Evidence on the indispensable nature of zinc and boron for higher green plants. Ibid., **1** (1926) 231–249.

(4) BRENCHLEY, W. E. and K. WARINGTON,: The rôle of boron in the growth of plants. Ann. Bot., **41** (1927) 167–187.

(5) JOHNSTON, E. S. and P. L. FISHER,: The essential nature of boron to the growth and fruiting of the tomato. Plant Physiol., **5** (1930) 387–392.

(6) EATON, F. M. and L. V. WILCOX,: The behavior of Boron in soils. Technical Bulletin, U. S. A., No. 696 (1939).

(7) MCMURTREY, J. E., Jr.: Distinctive plant symptoms caused by deficiency of any one of the chemical elements essential for normal development. Bot. Rev., **4** (1938) 183–203.

(8) MCHARGE, J. S. and W. R. ROY,: Mineral and N content of the leaves of some forest trees at different times in the growing season. Bot. Gaz., **94** (1932) 381–393.

result obtained shows merely the absolute amounts of the nourishing substances in the soil, so that the exact amounts that are assimilated by plants is not clearly known. Various methods for testing the efficient nourishable substances have been devised, but we still lack a simple and accurate method. All that can be done at present is to rely on certain well-tried methods(1) and obtain approximate results.

(I) **Edaphic indicators**

As we have seen in the preceeding section, the undisturbed type of vegetation which clothes a given tract of country is found to reflect very clearly the prevailing climatic factors, but variations with climatic zones are clearly related to differences in the nature of the soil. But the soil itself may, as we have seen, also ultimately be determined to a large degree by climate. Thus a pronouncedly podozolic soil is developed from a variety of rocks under appropriate climatic conditions, often carrying a similar type of vegetation. Physical differences in soil may however cause considerable differences in climate in the soil itself: thus a cold wet Clay may closely adjoin a warm light sandy soil, and the vegetation on the two soils may present marked differences.

As a rule, even when there are marked chemical differences in the parent rock, as between limestone, quartizite, and granite, the difference in vegetation is less determined by chemical than by physical differences in the soil. Some trees appear remarkably indifferent to soils, as is well illustrated by *Pinus tabulaeformis*, which is found on an extremely wide range of rocks; but here the hilly topography results in adequate drainage, which is the chief essential for the growth of this tree.

Bearing these considerations in mind, it can still be said that in the regions under consideration, certain soils with pronounced characteristics are commonly associated with certain plant species or types. Sometimes, under the same climatic conditions, the native vegetation may vary greatly and, in its extreme case, different communities may occur within a radius of only a few kilometers—differences usually due to the type of soil.

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(1) For extracting the nourishable salts, HEINRICH used a 1% solution of ammonium citrate; EMMERING, a 2% solution of the same, SIGMOND, 0.1–0.2% nitric acid; an experimentanl farm in Japan, a 1/5 normal solution of hydrochloric acid; DYER, a 1% solution of citric acid. The solution of the salts thus extracted are analysed and the efficient nourishable salts determined.

Since the relation between soil and type of vegetation is clearly shown in the approximate correspondence of the important zonal groups of soils with the main types of a plant community, it may be possible to read the same symbols given in the soil map of northern East-Asia (cf P. 484, Fig. 13), with other meanings from the viewpoint of vegetation.

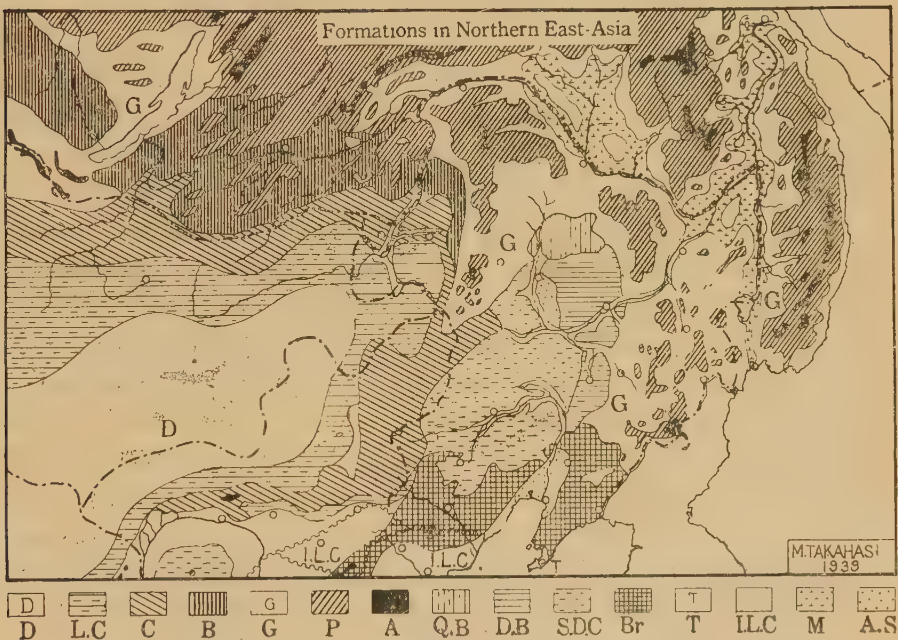

Fig. 31. Distribution map of vegetations as based on Formation—system[1] in the regions under consideration.

(D.) Semi-cold Desert Formation. (L. C.) Low Steppe Subformation and Scrub Steppe Formation. (C.) Mainly True Steppe Subformation partly comprising Prairie Formation as postclimax. (B.) True Prairie Subformation. (G.) Temperate (moist) summer-green Forest Formation partly comprising Temperate tall Herbage Wood Formation mainly in disturbed area. (P.) Cold-temperate needle-leaved Forest Formation. (A.) Arctic or Alpine Vegetation Panformation. (Q. B.) True Prairie Subformation partly under cultivation, comprising Postclimax Prairie Subformation. (D. B.) Formerly True Prairie Subformation, almost completely cultivated. (S. D. C.) True Steppe Subformation comprising Semi-cold wander Waste or Halophyte Formations. (Br.) Temperate (moist) summer-green Forest Formation comprising Temperate semi-dry needle-leaved Forest or Prairie Formations. (T.) Temperate semi-dry needle-leaved Forest Formation. (I. L. C.) True Prairie Subformation almost cultivated and partly Temperate semi-dry needle-leaved or moist summer-green Forest Formations. (M.) Hydrophytes Panformation with partly Hochmoor Formation. (A. S.) Semi-cold wander Waste Formation.

(1) Detailed explanations will be found later.

(1) **Indicators of soil water.**—A plant or community may indicate a deficiency or an excess of water, often accompanying secondary or concomitant factors. For example, xerophytes, generally, are associated with habitats of low water content as well as usually with high temperatures and low humidity, while hydrophytes indicate in a general way an excessive water supply and consequent poor aeration.

Many species, such as *Leonurus manshuricus* (cf Fig. 32) and *Carpesium cernuum* L., indicate a water table at or near the surface soil; others, such as *Ephedra distachya* (cf Fig. 33), *Glycyrrhiza uralensis* FISCH. et DC. (cf Fig. 34) and *Peganum nigellastrum* BUNGE (cf Fig. 35) indicate ground water at a great depth.

(2) **Indicators of sandy soils.**—Where the soil contains an admixture of sand, run-off is greatly reduced and the water penetrates to greater depths, often to 1 or 1.5 meters. This sandy-loam type of soil is clearly indicated by the abundance of certain characteristic species which are taller and more deeply rooted than the short grasses on the "hard lands", while sometimes the bunch-grass type of vegetation also prevails. Chief among these are *Artemisia Halodendron* TURCZ. et BESS. and *Stipa caduciseta* KITAG. (cf Fig. 36). *Agriophyllum arenarium* BIEB.[1] (cf Fig. 37) which is the most important type of vegetation in the Mongolian Regions, grows well on the nonalkaline, light-textured, deep, well drained soils of the uplands, for example, on stable deep sand dunes. Moreover following species are all indicating sandy soils:

Aneurolepidium chinense KITAG.,
Calamagrostis Epigeios ROTH,
Chloris virgata SW.,
Pappophorum boreale GRISEB.,
Allium bidentatum FISCH. et REGEL,
Corispermum elongatum BUNGE,
Stellaria dichotoma var. *lanceolata* BUNGE,
Pugionium cornutum GAERTN.,
P. verticillaris STEPH. et WILLD.,
Oxytropis oxyphylla DC.,
Peucedanum rigidum BUNGE,
Cynanchum sibiricum R. BR.,
Cymbaria daurica L.,
Olgaea leucophylla ILJIN,
A. dasystachys NEVSKI,
Aeluropus littoralis PARL.,
Hordeum brevisubulatum LINK,
Carex Kobomugi OHWI,
Pleuropteropyrum Chaneyi KITAG.,
C. puberulum ILJIN,
Thalictrum squarrosum STEPH. et WILLD.,
Potentilla betonicaefolia POIR.,
P. tanacetifolia var. *decumbens* TH. WOLF,
Thermopsis lanceolata R. BR.,
Gentiana decumbens L.,
Messerschmidia sibirica subsp. *angustior* KITAG.,
Echinops Gmelini TURCZ.,
Artemisia pubescens var. *oxycephala* KITAG.,
etc.

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(1) At the biginning of September the withered plants often form large blackish patches which can be recognised at a distance, on the sand hills or sandy soils, indicating their peculiar habitat.

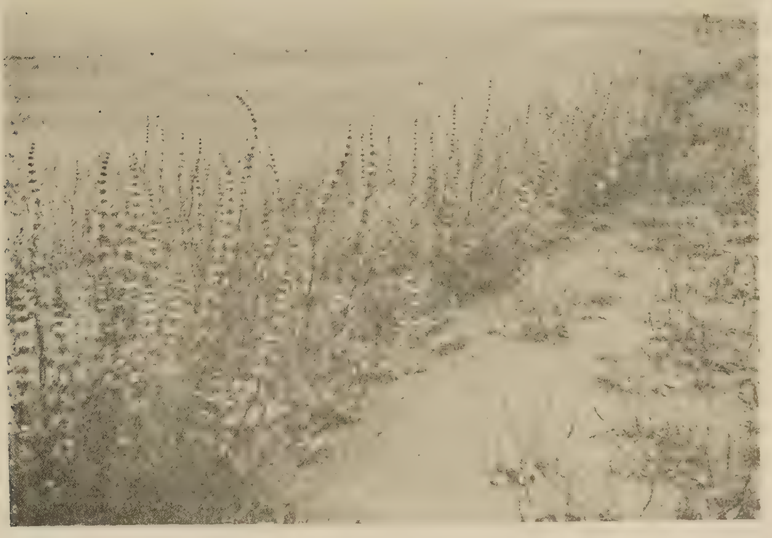


Fig. 32. *Leonurus manshuricus* YABE indicates the water table at or near the surface soil (face P. 540). (M. TAKAHASI)

Fig. 33. *Ephedra distachya* L. indicates ground water at a great depth (face P. 540). (M. TAKAHASI)

Fig. 34. *Glycyrrihiza uralensis* FISCH. et DC. indicates ground water at a great depth (face P. 540). (M. TAKAHASI)

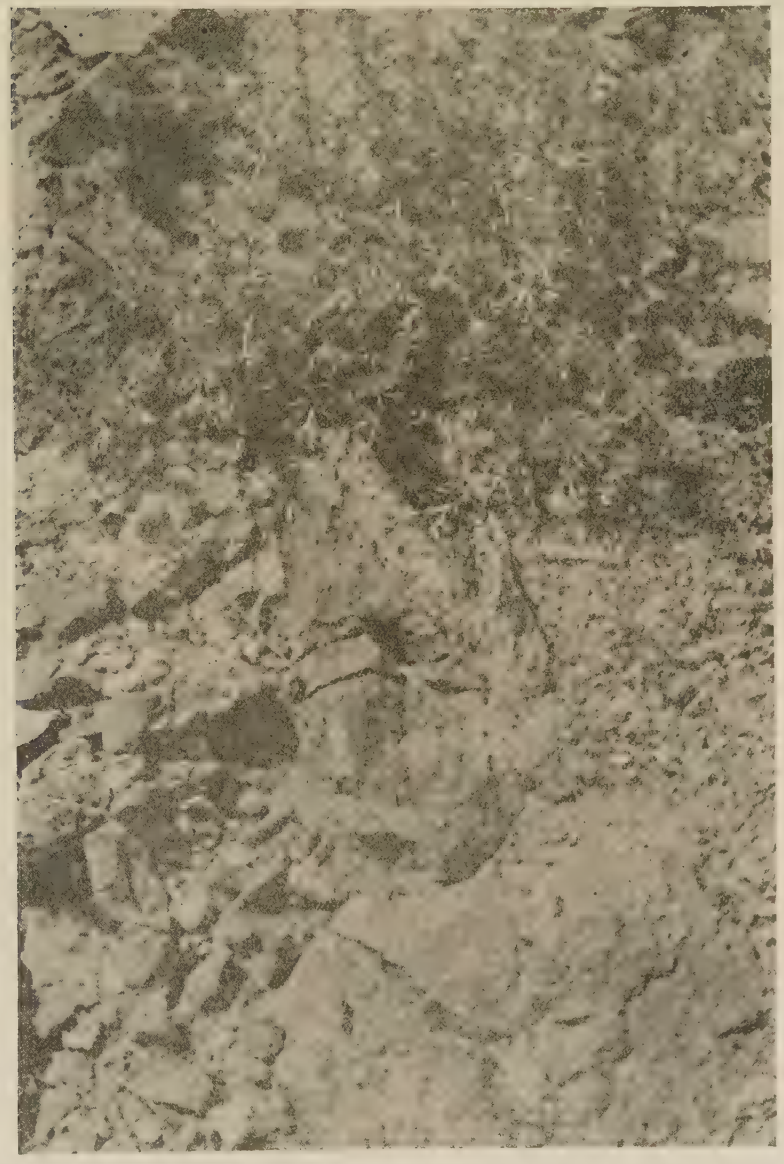


Fig. 35. *Peganum nigellastrum* BUNGE between rocks or their blocks in the southern Mongolia Region (face P. 540).

(M. TAKAHASI)

Fig. 36. *Stipa caduciseta*—Sociation on a considerably stable sand dune (face P. 540). (M. TAKAHASI)

Fig. 37. *Agriophyllum arenarium*—Sociation on a somewhat stable deep sand dune (face P. 540). (M. TAKAHASI)

(3) **Indicators of salinity.**—In the large parts of the Mongolia Reginon, rainfall is so light that the excessive salts of the soil, instead of having been leached away to the ocean, have accumlated, especially in lowlands, forming saline or alkaline spots, often of great extent; these have already been described under "Alkali Soils."

Such areas are characterized by communities of Halophyten, especially adapted to secure water from strong soil solutions. The following species indicate Saline or Alkaline Soils:

Salicornia herbacea L. (cf Fig. 38),
Atriplex Gmelini C. A. MEYER,
Suaeda corniculata BUNGE,
S. japonica MAKINO,
Anabasis aphylla L.,
Nitraria Schoberi L. (cf Fig. 39),
S. ambigua MICHX.,
Obione sibirica FISCH.,
S. glauca BUNGE,
Pleuropteropyrum sibiricum KITAG.,
Kalidium gracile FENZL.,
Limonium aureum HILL et O. KUNTZE, etc.

Kochia Sieversiana C. A. MEYER, a low-growing yellow whitish half-shrub, occupies the finer grained and easily puddled soils, where the subsoil is saline. The large, woody, somewhat spiny and bushy-topped *Atraphaxis manshurica* KITAG. occurs on more gravelly soil with a saline subsoil (cf Fig. 40).

In certain areas it is accompanied by *Aneurolepidium chinense* KITAG. On lower ground, these extensive salt-grass flats give way to more saline areas characterized by *Suaeda corniculata* BUNGE, *Obione sibirica* FISCH., and species of similar tolerance of salt.

The salt content in the soils of several communities decreases from 2.5 per cent in the salt flat to 0.5 per cent in the community of *Aneurolepidium chinense* KITAG., while in that of *Stipa baicalense* ROSHEV. the soil has only less than 0.1 per cent. It may thus be seen that each plant community indicates not only a certain concentration of salt or freedom from salinity, but also other edaphic conditions upon which the success or failure of crop production directly depends. This question will be taken up in greater detail later.

III. Physiographic factors

It will be convenient to bring together under this head the factors of the habitat that depend on (A) Land relief (land elevation and angle of slope), (B) Aspect (protection and exposure), (C) Geodynamic force (gravity, water current, and similar factors). It is obvious that these factors affect vegetation largely through climatic and partly through edaphic factors.

(A) Land relief

As a rule, the greater the altitude the damper the atmosphere, (apart from the local effects of protection and exposure), because moisture-bearing winds are cooled as the air ascends (it may be reasonable to regard this phenomenon as a kind of adiabatic expansion under "the law of CARNOT's cycle"), so that their relative humidity rises. The annual precipitation also rises steadily with altitude, an increasing amount of it occurring as snow. The excessive snowfall of subalpine and alpine regions, besides accounting for many of their characteristic features, explains the generally high water-content. Winds are usually prevailing and forceful, with both direct and indirect effects on the dwarfing of trees at the timber line, as already mentioned.

The vegetation of steep-sided ravines usually differs greatly from that of exposed ridges or plateaus. It is protected from wind (except where the axis of the valley coincides with the direction of strong prevailing winds), and the water vapour arising from the vegetation therefore tends to accumulate; it is also often sheltered from the direct rays of the sun. The vegetation therefore tends to be hygrophilous, relatively to that of the exposed ridges or plateaus.

The effect of the angle of slope is important in more than one way. First it determines, in relation to the height of the sun, the angle at which the incident rays strike the ground, whence the heating effect of insolation. In the tropics, flat ground gets the full effect of the vertical rays, in high latitudes the southern exposure of a slope that receives the rays of the midday sun at right angles is in the same position.

Second, the angle of slope largely determines the amount and type of soil that accumulates. Since no soil can rest on vertical cliff faces and very steep slopes, the substratum for vegetation is necessarily bare rock. Hillsides inclined at a moderately steep angle can seldom accumulate any great depth of soil, hence are subject to great erosion. The water run-off and correspondingly the water-content of the soil, too, depends, of course, largely on the slope of the ground and also largely on the nature of the soil and on the velocity with which the rain falls, all of which questions have already been discussed under the appropriate headings.

(B) Aspect

The effect of aspect is everywhere related to differences in exposure, that

Fig. 38. *Salicornia herbacea* L. is indicating Saline Soils (face P. 545).
(M. TAKAHASI)

Fig. 39. *Nitraria Schoberi* L. indicates Saline or Alkaline Soils (face P. 545). (M. TAKAHASI)

Fig. 40. *Atraphaxis manshurica* KITAG. occurs on gravelly soil with a saline subsoil (face P. 545). (M. TAKAHASI)

is, the position of a slope with respect to the sun, acting through the temperatures both of air and soil, and thus through the relative humidity of the former and the water-content of the latter, and consequently, the nutrients and aeration. Slopes exposed to the sun's rays for the longest periods receive most heat (this question has already been dealt with under "Temperature"); thus slopes with a southern exposure regularly show somewhat lower humidities, higher evaporating power, and lower water-content than those with northern exposures. Under these circumstances, in arid or semi-arid regions, such as in North China, the effects upon vegetations are usually most pronounced, that is, a northern exposure will bear a more hygrophilous vegetation and with less risk of catching fires of any kind than a southern exposure.

The effect of wind is most pronounced on slopes exposed to prevailingly dry winds which, in the present regions are, as a rule, southerly or southwesterly. For these two reasons of exposure and wind, they are usually the driest slopes of hills and mountains. They are, further, the fundamental reasons that, in the arid or semi-arid regions like North China, the forests that still remain, especially the coniferous ones (except the *Pinus* species) are limited to northern exposures.

In the same way, the eastern slopes are cooler than, and not so dry as, the western slopes, because during the early afternoon the general temperature is higher than in the morning, and the same intensity of insolation is consequently able to raise the surface of the soil to a higher temperature. Under these differences of habitat factors, succession moves also much more rapidly and the climax is reached much sooner on the northern side, with the result that the communities on the northern slopes often differ greatly from those on the southern slopes of the same hill or mountain (cf Fig. 41).

(C) Geodynamic force

All the forces that mould land surfaces have one of two effects. To illustrate, the same topographic agent may do both, as when a stream erodes in its upper course and forms deposits along the other. That is, the materials eroded by streams are brought down to a lower level and deposited where the current is checked. These gravels, sands, or silts either accumulate at various points in the courses of streams, or form deltas at the mouths of rivers, providing new habitats for plants. The success of the initial invasion of plants depends on the kind of surface laid bare and on the water content as

determined by the surface, the slope, and the climate of the region. The form and nature of the area are unimportant except as they affect these factors.

Under natural conditions, soil erosion is usually more severe in semi-arid and arid regions than in more humid areas; and different kinds of soils erode in somewhat different ways. In China, soil erosion, and more especially loess erosion, which have been discussed by many writers, are at the present time receiving considerable attention on the part of pedologists, geologists, geographers, ecologist, agriculturists, and engineers in connection with river control. The types of soil erosion and their control will be treated later.

Gravity itself also produces bare areas by pulling down materials that have been freed by weathering. It is in mountain regions, where vertical rock faces and steep slopes abound, that talus accumulates at the foot of cliffs, and the erosive power of flowing water, or of frost, is at its maximum. Landslide in mountains (cf Fig. 42) as well as heavy snowslides often produce extensive bare areas. Owing their hardness, dryness, and their steep or vertical faces, areas thus produced are usually among the slowest to be invaded. Of these bare areas, due to the various factors mentioned, flood plains and channel deposits perhaps prevail most in North China. The flood waters, which reach higher levels than usual, are ponded back into depressions rarely reached. Moreover, they cover the lowlands for a much longer period. In these places, the previous vegetation, covering large areas, is either, washed away, covered with silt, or killed by the water, and the area is bared for a new development or succession. Since these are usually shallow and subject to evaporation, development in them is nearly always short.

In older times, the present Shantung (山東) Peninsula was an island, the ancient Hwang-Hai (黄海) covered Hopei (河北) and Honan (河南), the mouth of the Hwang-Ho (黄河) was west of Kaifeng (開封), where it deposited its burden of sediment washed down from the loess-covered highland of the west. Gradually, the delta grew and the shallow sea become filled as far as the present North China Plain, whence the plain may be called a gift of the Hwang-Ho.

Even at the present time, these rivers in North China, by continuously depositing their surplus load, build up their beds. The channels become filled with sediments above the level of the surrounding land, and during the heavy rains of July and August, the rivers, which rise very rapidly, easily break through their dikes in spite of the great embankments to keep them in their channels. Whenever this occurs, there is not only great loss of life and

Fig. 41. Distant view of *Picea Mastersii—Larix Principis-Rupprechtii*—Consociation growing on a northern slope of Mts. Wutai-Shan (face P. 549). (M. TAKAHASI)

Fig. 42. Landslides on steep slopes of Mt. Hakutosan produce extensive bare areas (face P. 550). (M. TAKAHASI)

Fig. 44. Distant view of *Picea Mastersii—P. Meyeri*—Sociation on Mt. Wuling-Shan (face P. 555). (M. TAKAHASI)

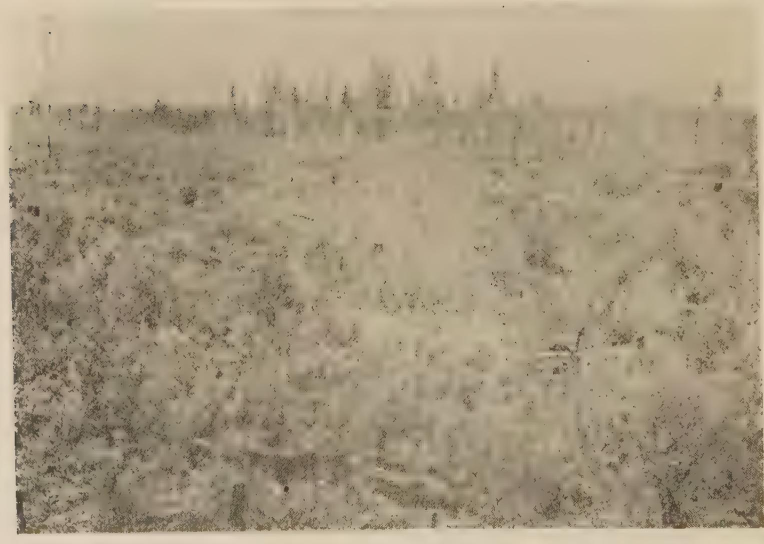
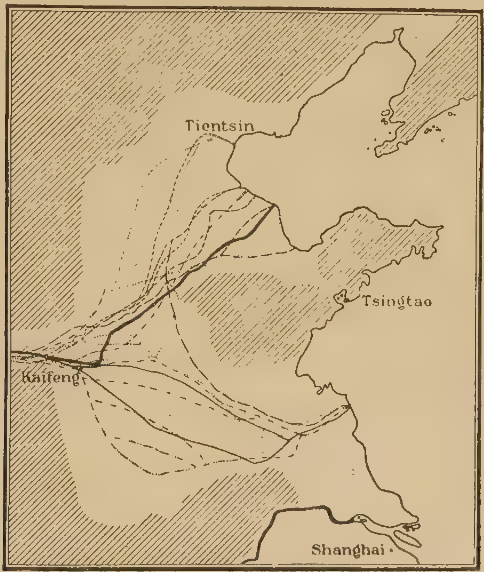


Fig. 45. Fires of recent occurence are indicated by *Chamaenerion angustifolium* SCOP. at the foot of Mt. Hakutosan (face P. 557). (M. TAKAHASI)

property, but also a change in the vegetation and in the nature of the soil. Some farms, formerly fertile loamy lands, transform to sterile sandy wastes. Little wonder that the Hwang-Ho, the most potent of these rivers, is called "China's sorrow."



LEGEND

- Course of the Hwang Ho from the great flood of B.C. 2297 down to B.C. 602
- Course during the third century B.C.
- Channels during the Tang and five succeeding dynasties, from A.D. 70 to A.D. 1048
- Course during the Sung Dynasty, 1048 to 1194
- Course during the Kin Dynasty
- Courses under the Yuen, Ming and Manchu Dynasties from 1280 1851
- Present channel
- Mountains

Fig. 43. Changes in the course of the Hwang-Ho (黃河).
(after CHIN HU WEI)

During the flood of 1935, in western Shantung, some of the deposits of the Hwang-Ho exceeded two meters in thickness. The river has also shifted its course many times, and its mouth which was first north of Shantung Peninsula, is now south of it. Prior to 1852, it entered the Hwang-Hai south of Shantung, while today it flows north of it, 250 miles distant from its former outlet. These changes illustrate the manner in which the great plain has been formed (cf Fig. 43).

(D) Physiographical indicators

Plant communities owe their significance as indicators of this kind mainly

to direct factors, especially water-content and nature of the soil. In the great majority of bare areas, however, physiographic causes or processes are so important and controlling that the seral indicators are readily correlated with them and their changes. As already emphsized elsewhere, causes other than physiographic may produce similar bare areas and initiate the same sere. The seral indicators of cliffs, rock-fields, and gravel-slides have acted as indications of landslide, snowslide, and various kinds of severe erosion. The indicator values associated with high altitudes are primarily due to temperature or water, or usually to both acting together. The sharp changes in climate with altitude produce a corresponding sequence of climaxes, which serve as the most outstanding of indicators. Certain growing-forms, such as Geophytes, appear to owe their character or at least their dominance to this sharp change, as pointed out by C. RAUNKIAER,[1] in addition to which, the majority of montane and alpine species have rather definite lower and upper limits which may be used as indicators of altitude, though a correction is necessary for those of wide range in latitude.

IV. Biotic factors

(A) Influence of man

Although man is constantly turning natural vegetation to his own use, cutting forests, using grassland for pasturing his flocks and heards, he usually does these things ignorantly and therefore wastefully, without foresight, because he has no adequate understanding of the conditions that govern the maintenance or regeneration of the kinds of vegetation he uses, nor any sufficient intelligent anticipation of what will result from his actions. In causing forest fires, he is also a powerful agent in upsetting the balance of Nature and producing forms of vegetation which by no means indicate what the habitat would produce under natural conditions. So the time is now opportune for studying the vegetation, particularly, because the natural vegetation of the whole of northern East-Asia is being destroyed or radically modified at an increasing pace, as had been done in China proper for centuries past, and unless we do it now, we shall not only be losing forever the opportunity of acquiring knowledge, but shall instead be making mistakes that can be avoided by timely investigations.

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(1) RAUNKIAER, C.: The life forms of plants and statistical plant geography (1934).

A traveller in North China will notice that, everywhere, irrespective of mountain or field, there is almost no forest to speak of except in the neighbourhood of Mt. Wuling-Shan (霧靈山), Mts. Wutai-Shan (五台山), Mts. Hsiao-wutai-Shan (小五台山) and the mountains near the town of Ningwufu (寧武). But the greater part of these famous forests are now almost deforested, with only a part of them remaining in some locations beyond easy access. As evidence, however, that formerly more prosperous forests existed in a number of places in North China, the writer has met with many massive roots of large trees in these mountains and elsewhere. What then is the principal cause of the present treelessness? The writer's answer to this is the devastating work of man in North China Mauntains and the ravages of Aeolian Sand in south-western Manchoukuo, although even in the latter, deforestation by man seems not to have been infrequent. Aeolian Sand has changed the nature of the soils of a region entirely, resisting all efforts to restore the present wilderness to the woodland of the past. This question has already been discussed under "Wind" and "Sand".

The intensity or thoroughness of the clearings from lumbering determines whether the result will be a change in vegetation or the initiation of a new site. The latter occurs only when destruction of vegetation is complete or so nearly complete that the pioneers dominate the area. Moreover, the writer is able to furnish evidence by actual examples of the fact that much soil finds its way from hills into valleys by a process known as creeping. Probably the most usual case of soil creep in China is due to agricultural practices. Every time a farmer hoes the land, and every time he pulls a weed, the soil is pushed a little farther down hill. The writer has frequently recognized (with J. Thorp) that in one cultivation or in one preparation of the soil for planting, the surface, 15 or 20 cm thick, may be pushed 20 cm or more down the hill. He has also frequently observed the natives reclaiming steeply inclined land in a mountain far from any village, cultivating *Glycine Max* Merr., *Vigna sinensis* Endl., and *Setaria italica* Besuv., which however were in such poor condition as hardly to promise any yield. One could not but be amazed at the ignorance of these natives who are repeating such follies, indifferent to past experience, and virtually contributing to the future occurrence of landslides.

Measures for controlling these landslides would go a long way toward lessening the silt burden of the rivers. Strip farming,(1) combined with terracing

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(1) Strip farming consists in planting strips of close-growing uncultivated crops, such as alfalfa or grasses, between the cultivated crops, such as corn, millet, wheat, and beans.

on the hillsides, seems to be the best answer to this problem. Skilfull farmers are already practising the latter but the former has never yet been tried out anywhere in China.[1] Especially on steep slopes, it is desirable to have strips of grass or leguminous crops between cultivated areas, and following contour line. The steepest of hillsides should be planted to forest trees, in which case also, it is desirable that the rows of trees shall follow the contours of the land instead of going directly up and down hill. Another method of controlling erosion, and which at the same time is a very efficacious one for conserving moisture, is that of planting crops on the edges of small pits which are dug every half meter or more over the fields. This method will be most effective when used in conjunction with strip farming.

Bare areas may by caused by removal, by deposit, or by stirring of the soil in places. Roads and railroads are universal examples. On the surface of strip mining for coal or iron, especially in Sanshi, large areas are laid bare and the raw subsoil brought to the surface. Gravel pits and deposits formed by dredging and draining are further examples. Poisonous gases from smelters, factories, etc., sometimes result in complete denudation, although the effect is usually seen in changes in the vegetation.

The writer has frequently found burnt stumps also, from which it may be concluded that trees burnt down, whether naturally or by man, must form a certain percentage of the destroyed trees, and thus constitute another cause for treelessness. Most fires in woodlands completely denude the burned area, but surface fires and top fires may merely destroy only a part of the population. Fires in grassland practically never produce bare areas for colonization. This matter will be dealt with in greater detail in the next section.

Many dwarf forests of *Quercus mongolica* owe their existence to the remarkable power of this species to withstand repeated burning and to establish itself on burnt grassland. In the very large areas exposed to fire resistance to it is most important. The purity of such *Quercus* forests is largely attributable to the fact that its associates are less resistant, and that none of them seem able to establish high forests in periodically burnt grassland. In the coniferous forests, especially of upper montane or subalpine regions, since the important species are fire-tender, fires are very destructive, but the removal of the layer of undecompose needles may provide a good seedbed if seed reaches the area; *Pinus* or *Larix* is favoured more than the

(1) THORP, J.; Geography of the Soil of China. (1936) 462–470.

other species because it seeds more freely and the seedlings can stand more exposure.

(B) Burning indicators

While fire has some points in common with other agencies responsible for denudation, it differs especially in its action upon the surface soil and in the more or less complete destruction of plants, as well as in the fact that the soil is not actually disturbed. These differences are reflected in the large number of indicators more typical of it than to other processes. Fires of recent occurrence are indicated by such characteristic annuals and perenials as *Chamaenerion angustifolium* Scop., *Carduus crispus* L., *Achillea Millefolium* L., *Epilobium palustre* L., *Pteridium aquilinum* Kuhm., and other species with wind-blown propagules.

Certain growing-forms appears to owe their character, or at least their dominance, to fire. The bush or scrub type is a characteristic fire indicator in forest climaxes the world over, where form, and consequently dominance, are because of the root-sprouts produced after fire. In the eastern and northern parts of the present regions, burnings are frequently characterized by various shrubs, such as *Rubus arcticus* L., *R. crataegifolius* Bunge, *Corylus mandshurica* Max., *Vaccinium uliginosum* L., and *V. Vitis-Idaea* L. The number and distinctness of these seral communities and their duration depend chiefly on the extent to which they have burned.

Fire has also played a similar rôle in making certain genera and species of trees almost universal indicators of its action, the best known examples being found in *Populus* and *Betula*, which owe this property to their ability to form root-sprouts, in consequence of which, the trees often or regularly consist of several stems. In the eastern or northern forests, the shrubs are normally replaced by *Populus Davidiana* Dode, *Betula platyphylla* Sukat., (or *B. platyphylla* subsp. *mandshurica* Kitag.), *B. davurica* Pall., *B. costata* Trautv., *Quercus mongolica* Fisch. et Turcz., *Tilia amurensis* Rupr., or *Alnus sibirica* Fisch., which later give way to a climax forest. In the *Picea jesoensis*—*Abies nephrolepis*—Consociation of the East Manchuria Mountains, *Populus*, *Betula*, or *Tilia* form remarkably permanent communities over an enormous extent as the result of repeated burns. Such seral communities not only indicate the possibility of reforestation, but they also make it clear that artificial means, such as periodic removal of the forest, must be resorted to where it is desirable to maintain the community as a relatively permanent type.

Another striking group of indicators is found among the conifers, *Pinus* genus, *Pinus densiflora* SIEB. & ZUCC. and *P. tabulaeformis* CARR., especially, being the most characteristic species.

(C) Indicators of productive arts

The natural plant cover is a result of all the growing conditions where it is produced. It is an index or measure of the factors influencing its growth and serves as an indicator of the possibilities of producing other plants on the land. Consequently, it is invaluable in classifying lands in regard to their suitability for agriculture, or forestry. If agriculture is possible, indicators may be used to denote the greater feasibility of humid, dry, or irrigation farming or the importance of combining grazing with dry farming.

Similarly, vegetation may be used to determine the possibility of afforestation or reforestation as well as the most promising dominants for any particular region.

(1) **Indicators of agriculture.**—The most reliable natural indicators of the agricultural possibilities of a region are to be found in its native vegetation. The Russian pioneers in the San-Ho (三河) Valley in northwestern Manchoukuo have been settling on lands covered with *Betula davurica* PALL. This is because these lands are more prosperous than those with *Larix Gmelini* LEDEB. et GORD. and *Quercus mongolica* FISCH. et TURCZ.

In the same way, *Artemisia sibirica* MAX. or *Primula farinosa* subsp. *Xanthophylla* KITAG. indicate their growing soils, being more prosperous for wheat and oats cultivation than those of *Stipa baicalensis* ROSHEV. or *Aneurolepidium chinense* KITAG. in the same region.

In the Mongolia Region, a good stand and growth of *Aneurolepidium chinense* indicates land that is well adapted to both dry and irrigation farming; but where the stand is thin and the growth poor, depth of good soil is usually too limited for profitable crop production, at any rate without irrigation. Conversely, *Stipa baicalensis* indicates land unsuitable even for dry farming, although it may be made to produce good crops when the excessive salt is removed by irrigation and drainage. *Phlomis mongolica* TURCZ., *Takeikadzuchia Lomonossowii* KITAG., *Gentiana decumbens* L., *Delphinium gradiflorum* L., *Papaver nudicaule* L., etc., are typical of comparatively moister fields of True Steppe Subformation in the southern half of Inner Mongolia (cf Fig. 46). More generally speaking, since a dense stand of mid grasses is indicative of favourable possibilities for the production of crops, so the boundary between True and Low

Fig. 46. *Phlomis mongolica* TURCZ. (left in the front), *Takeikadzuchia Lomonossowii* KITAG. (right in the front), *Gentiana decumbens* L. (left in the middle rank), *Delphinium gradiflorum* L. (middle in the middle rank), *Papaver nudicaule* f. *arenicola* KITAG. (right in the middle rank), etc. :— These occur in True Steppe Subformation in the southern Mongolia Region.

Limonium bicolor O. KUNTZE (background) :— This occurs in Low Steppe Subformation in the Mongolia Region (face P. 558).

(M. TAKAHASI)

Fig. 47. *Betula platyphylla* SUKAT., a typical indicator of the former forest deforested by burning or lumbering (face P. 561). (M. TAKAHASI)

Fig. 48. *Vitex chinensis* MILL., seen on the left hand side under the *Pinus tabulaeformis* trees, is one of the most prominent indicators of overgrazing (face P. 563). (M. TAKAHASI)

Steppe Subformations approximately coincides with the limitation to reasonable farming. These general principles probably apply, in the main, throughout much of the Mongolian Plateau, whence, as consequence, a belt of abandoned fields and farms may be seen in the transitional zone of these two Subformations. That is, there have been several waves of settlement, coinciding more or less closely with the periodismus between drought and wet phases.

(2) **Forest indicators.**—Forest indicators are of three chief types, namely, those that have to do with existing forests, those that indicate former forests, and those that indicate the possibility of establishing new forests. Obviously, every forest climax indicates a forest climate, although of different quality. The deciduous forest indicates one with long, hot summers and moderately cold winters, with an abundance of both summer and winter precipitation. The forest community that is the climax for a region indicates the type of forest that will naturally develop or redevelop in all bare or cleared areas. The various groupings of species and the differences in density and growth of dominants and subdominants serve to denote differences in edaphic conditions and minor changes in the factor complex.(1) Seral communities, likewise, indicate differences in edaphic conditions or other habitats, often indicating the nature of the original area (whether wet or dry) or the nature of the disturbance (such as fire, wind throw, lumbering, etc.) or the particular stage in the development of the succession.

(a) **Indicators of former forests.** These indicators are either actual relics of the former forest itself or seral communities that mark particular stages of succession toward reforestation. They gradually pass into indicators of the possibility of forest production (indicators of planting) in regions that have been repeatedly deforested. Their great value lies in the fact that they not only indicate the possibility of reforestation, but also the stage that has been reached and further methods to be employed.

Populus Davidiana DODE; *Betula platyphylla* SUKAT. (or *B. platyphylla* subsp. *manshurica* KITAG.), *Tilia amurensis* RUPR. and *Quercus mongolica* FISCH. et TURCZ. are typical indicators of former forests that have been deforested by burning or lumbering throughout northern or northeastern Manchoukuo (cf Fig. 47).

(b) **Indicators of planting.** Indicators of sites for planting are of two

(1) MOORE, B.: Biological forest types in the Adirondack region. Ecology, **16** (1935) 648–651.

kinds, namely, those that indicate the former presence of a forest, and those that suggest the possibility of developing forest in grassland or scrub areas. These are indicators of reforestation and afforestation respectively.

The obvious indicators of reforestation are relic survivors, or trunks and stumps. Charry fragments of wood or pieces of charcoal in the soil, although less obvious, are equally conclusive. Where there is no direct evidence of the original forests, indirect evidence is often furnished by indicator communities which bear a direct relation to forest. Such are seral communities that show a successional relation to the forest climax and the societies of herbs that have formed layers in them.

Thus, areas of *Phellodendron amurense* RUPR., *Acer mandshuricum* MAX., *Acer tegmentosum* MAX., and *Acer pseudo-Sieboldianum* KOM. with *Dryopteris crassirhizoma* NAKAI, *Equisetum hyemale* L., *Lycopodium clavatum* L., *Lycopodium serratum* THUMB., *Maianthemum bifolium* F. W. SCHMIDT, *Polygonatum japonicum* MORR. et DECAISNE, *Oxalis acetosella* L., and similar mesophytic herbs indicate former forest lands.

In reforestation, it is the general rule to employ the species of climax trees that were in possession, unless special circumstances or purposes may make it desirable to employ a certain pioneer tree. For example, species growing in contact with grassland at certain places give the key to the selection of those best adapted for afforestation. Thus, *Pinus sylvestris* L., brought from the foothills, has been successfully grown in the grass-covered sand hills of northern Outer Mongolia, while in southern Manchoukuo and neighbourhood *Pinus densiflora* SIEB. & ZUCC. or *Pinus tabulaeformis* CARR. is also one of the best species for planting in gravel or sandy, well drained soils.

(D) Animal and insect influences

Moderate grazing helps the seeds of certain species to be trodden into the soil and also regulates to suit conditions that may be helpful in reducing the amount of undergrowth, in exposing the mineral soil and mixing it with the humus, and sometimes in reducing fire hazard or fire damage. But in most cases there are, on the contrary, damages done by the overgrazing of domestic animals, such as oxen, horses, camels, goats, and sheep, all so indispensable to Mongolian nomadic life. The sheep and goats of the Chinese, who live a life, half husbandry and half stock-farming, cause no less damage than that from deforestation by man, who alone, it is true, can cut down large trees, but nothing can surpass the damage done by these domestic animals in eating up young leaves and destroying saplings.

In North China and southern or southwestern Manchoukuo, we used to meet with flocks of goats and shepherd boys herding sheep everywhere in the mountains and fields. The goats, of which there are many, especially on the hills and terraces in North China, have brought about surprising changes in the vegetation. In regions where damage from them is most marked, *Leguminosae* and *Gramineae*, the favourite herbage of these domestic animals, cannot grow satisfactorily, while *Vitex canabifolia* SIEB. et ZUCC., which does not seem palatable to them, grows vigorously, covering wide tracts of field and hill (cf Fig. 48), as also species of *Clematis*(1), *Delphinium*(2), *Veratrum*(3), *Cimicifuga*(4), *Thymus*(5), etc.(6) It will be found that practically every tree or shrub, such as *Zizyphus jujupa* MILL., is characterized by either thorniness, or marked dwarfishness, but mostly by both these properties, all other species having been eliminated. A good illustration of this damage is found near Chengteh (承德). As the photogragh shows(7), a dilapidated roof of a desolate lamasery seems to be the only safe place here in which poor young trees can grow, the writer having failed to find even a single young tree on the ground near by. Such a scene would not be very strange in a damp region, but in a comparatively dry region like North China, and that on a roof or a castle-wall, where naturally the conditions for growth are of the most difficult kind, the plants seem to withstand the rigors of climate and lack of nourishment without seeking more hospitable ground elsewhere. This is the most eloquent testimony to the injury to plants perpetrated by domestic animals. However luxuriously the trees may grow and form a splendid forest, they are doomed to die sooner or later, with young trees of the next generation to take their

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(1) *Clematis fusca* TURCZ., *C. heracleifolia* DC., *C. hexapetala* PALL., *C. koreana* KOM., *C. mandshurica* RUPR., *C. serratifolia* REHD., *C. tubulosa* TURCZ., etc.

(2) *Delphinium grandiflorum* L., *D. grandiflorum* var. *chinense* FISH., *D. Maackianum* REGEL, etc.

(3) *Veratrum dahuricum* LOES., *V. Maakii* REGEL, *V. nigrum* L., *V. patulum* LOES., etc.

(4) *Cimicifuga dahurica* MAX., *C. heracleifolia* KOM., *C. simplex* WORMS., etc.

(5) *Thymus asiaticus* KITAG., *T. quinquecostatus* CELAKOV., etc.

(6) *Allium anisopodium* LEDEB., *Iris biglumis* VAHL, *I. dichotoma* PALL., *Thalictrum aquilegifolium* L., *T. simplex* L., *Papaver nudicaule* L. and its f. *arenicola* KITAG., *Bupleurum scorzoneraefolium* WILLD., *Gentiana decumbens* L., *Convalvulus Ammannii* DESR., *C. chinensis* K. GAWL., *Hyoscyamus agrestis* KITAIB. et SCHULT., *Patrinia heterophylla* BUNGE, *P. scabiosaefolia* FISH. et LINK, *P. scabra* BUNGE, *P. villosa* JUSSIEU, *Artemisia annua* L., *A. pectinata* PALL., etc.

(7) TAKAHASI, M.: An ecological study of vegetation in the province of Jehol, Manchoukuo. Rep. First Sci. Exped. sect. IV. part III (1936) Fig. 55.

places. But if from any cause, the young trees, that is the next generation, fail to grow, the forest must then inevitably go to decay, leaving the fields and mountains quite treeless.

Grazing usually leads to the replacement of woody undergrowth by more inflammable grass and a generally drier type of vegetation, increasing considerably the chances of fire either through carelessness or design.(1)

After fire, grazing is probably the most influential factor controlling the composition of the forest over most of the country. Commonly associated with grazing damage is lopping for fodder and fuel, and the many other injuries inflicted by the graziers. Under natural conditions, however, it is unlikely that wild animals, such as deer and wild boar, ever do enouch damage to influence the types of vegetations, as the result of undue multiplication and regenerating properties. In some places, such as the densely populated steppe in eastern Mongolia, however, the burrows of *Myospalax* are sufficiently serious as almost to completely denude whole areas.

As a matter of fact, the writer found a considerable number of dead trees in the region of Mt. Wuling-Shan (霧靈山) and other formerly forested areas. Careful examination disclosed many holes in the trunks of these dead trees as witness to the injury done by larva of beetle, for which reason the writer does not hesitate to include injury by insects among the causes of present treelessness in the regions concerned. Generally speaking, this damage occurs when trees, through various influences of environment, are already tending to decay, so that it is a factor for accelerating decay. But what is worse, the natives, believing that the injuries to trees and crops by insects were the result of "force majeure," took no counter-measures, for which reason we should estimate insect damage to be much higher than under ordinary conditions.

In some years, in North China, locusts are known to completely destroy annual crops. PEARL S. BUCK, in her famous Chinese novel entitled "The Good Earth", speaks of these calamities.

It therefore seems that, although in different degrees, all these causes have acted together in bringing about the present deplorable tree famine, the only remedies being systematical afforestation, construction of reservoirs, waterways, etc., although it is necessary at the same time to prohibit pasturage on woodlands, rooting up of grown grasses for fuel, and the meaningless

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(1) DAUBENMIRE, R. F.: Plant succession due to overgrazing in the *Agropyron* bunchgrass prairie of southeastern Washington. Ecology, **21** (1940) 55–64.

reclamation of slopes, as well as to eliminate *Vitex canabifolia* SIEB. et ZUCC, by artificial means, such as burning to enable the growth of plants for grazing, to which must be added strict control over deforestation.

(E) Indicators of grazing

In grazing practice, five classes of stock must be considered, namely, cattle, horses, sheep, goats, and camels. Each has more or less its own definite preferences regarding the type of vegetation grazed, and affecting the pasture or range in a different manner, the particular type of vegetation determining whether they, or a combination of two or three, are preferable. The more palatable species are eaten down, thus rendering the uneaten ones more conspicuous. These conditions have already been treated in the preceding section. Overgrazing or trampling for a certain period will produce indicators which may easily be recognized. Obviously these indicators are not the same everywhere in the regions concerned. If grazing is sufficiently severe, less palatable species, too, may disappear unless they are woody, wholly unpalatable, or protected by spines. The predominance, therefore, of annual weeds and short-lived, unpalatable perennials indicates severe overgrazing, besides characterizing the pastures to be in advanced stages of depletion.

Prominent among these are *Polygonum aviculare* L., *Artemisia pectinata* PALL., *Allium anisopodium* LEDEB., *A. senescens* L., *Vitex chinensis* MILL., *Delphinium grandiflorum* L., *Iris Pallasii* FISCH., etc. Characteristic species representing a less pronounced degree of ovegrazing are *Lepidium apetalum* WILLD., *Thymus mandshuricus* RONNIG., *Achillea Millefolium* L., *Carduus crispus* L., etc. The early indicators of range deterioration are decrease in abundance of the more valuable species of grasses, such as *Stipa* and *Agropyron*. This is followed or accompanied by marked increase in the vigor and abundance of species, such as *Artemisia*, *Solidags*, *Aster*, etc.

Some species indicate such processes as trampling, for example, *Plantago asiatica* L., *P. depressa* WILLD., *Polygonum aviculare* L., etc.

(F) Competition among plants

The normal length of life of a tree may also be an influential factor in species competition, a long-lived species being at a considerable advantage, since it is able to hold a place once gained, and to continue seed production for a long period.

It is probably no coincidence that notoriously long-lived species also tend

to be the common ones, and it is evident that other advantages, such as rapid growth, abundant production of fertile seed with a good dispersal mechanism and seedling adaptation to the special rather unfavourable conditions, may be equally effective. This question will be treated in greater detail when dealing with succession.

The effect of root competition has been studied by numerous investigators, especially in the case of herbaceous plants. The amount of available moisture is greatly increased by the elimination of root competition, and in very dry periods from two to nine times as much moisture is available in the top 15 centimeters of soil in the trenched quadrats as in the untrenched. The competition comes largely from the herbaceous and shrub flora of the forest floor. *Betula* has about 50 per cent of its roots in the top 35 cm of soil and *Picea* about 70 per cent, most tree species having by far the major portion of their absorbing surfaces in the top one meter of soil. The effect of root competition from grasses and other herbaceous plants may also be very serious.

The degree of adaptation to the locality factors varies widely; and within limits, the closer this adaptation the more favoured the species in its competition with others. Some species, however, especially those found in extreme types of habitat, such as in salt marshes, appear to have lost the power of adjusting themselves to changed conditions and soon drop out if such a change occurs, whilst other species appear able to adapt themselves to a wide range of conditions. Such adaptability being a great asset in competition, it is naturally enough frequently met with in widely distributed species. But since many species cannot regenerate under their own shade, either from lack of light or owing to an unsuitable seed bed, they are not likely to reoccupy any gaps opened by the death of a large tree of their own kind if competition of other species is at all severe. The best examples are furnished by the *Larix* species, such as *L. olgensis* HENRY, *L. Principis-Rupprechtii* MAYR, *L. Gmelini* GORD. and *L. Cajanderi* MAYR, which are admirably adapted to their characteristic habitat of new gravelly alluvial cones, volcanic pumice slopes, or swampy valleys between mountains; all of which may be mainly through failure of the seedlings under competition to obtain light. Even when planted, seedlings several years old grow well under the habitat of the various kinds just mentioned. *Pinus densiflora* SIEB. et ZUCC., *P. sylvestris* L. and *P. tabulaeformis* CARR. flourish on a comparatively wider range of altitude, rock, and soil, good drainage being all that is required.

It should be noted that many species which are found mainly on poor

soils are established there, not because they grow best on such soil, but because they fail to thrive in competition with other species on richer soils and consequently can hold their own only on the poorer soils.

Plant Community

I. Succession and Climax

(A) **Succession**

(1) **Primary** (Normal) **succession.** — With the conditions of newly formed soils still unfavourable, the number of species which, at first, is relatively small, gradually increases, resulting in considerable variation setting in later. Variation here is mostly owing to differences in moisture conditions themselves, affected by the depth of the water table, the texture of the soil, and the climate. Naturally, there will also be differences resulting from the nature of the adjoining older vegetations and the quantity of seeds they supply. The vegetation that had first established itself on a new site is in time replaced by others which, also in their turn give way to other vegetations, until eventually a stage is reached in which the last vegetation is apparently in harmony with the climate and with the factors related to the site, when no further changes are evident. This progression in time is what is known as primary succession, and the final stage as climax vegetation.

The primary succesional changes observed in the course of the enumeration usually include the following six kinds of Seres[1] according to their areas of origin.

Hydrosere	the sere commencing in water or moist sites.
Xerosere	the sere commencing upon dry sites.
Lithosere	the sere commencing upon bare rocks.
Halosere	the sere commencing in saline water or upon saline soils.
Oxysere	the sere commencing in acid aquatic media or acid soils.
Psammosere	the sere commencing upon loose sands.

Thus the possible relationships between each developmental series in succession can be traced and in each case the diagramatical expression[2] is

(1) A unit plant succession, comprising the development of a community from the pioneer stage to the climax.

(2) PITT-SCHENKEL, C. J. W.: Some important communities of Warm temperate Rain Forest at Magamba, West Usambara, Tanganyika Territory. Jour. Ecol. **26** (1938) 50–75.

recommended for the benefit to show their mutual ecological ranks at the same time.

(2) **Secondary succession** (Resuccession).—When the adverse influences that have brought about retrogression have been removed, or when an area, on which the forest has been destroyed and replaced by grassland or arable cultivation, has been left to itself, progress at once reasserts itself and a secondary succession, or resuccession, takes place, although, naturally, it is not always easy to distinguish between corresponding stages of the primary and secondary successions and the retrogression stages.

In northern or eastern Manchoukuo many parts of the former climax forests have been destroyed and grasslands taken their places. But, in time, seedlings of woody plants that gradually colonize the grasslands may shoot up, and if strong or numerous enough, they will thin out the grasses along the course of the secondary succession. Primary succession in a thickly populated country like North China very rarely reaches the climax type undisturbed. Except in northern and eastern Manchoukuo and in the Russian Far East, there appears to be little forest in the regions under consideration that have escaped the consequences of human settlement in the past, with the vegetation altered by burning. grazing, lumbering, and other forms of interference. For the sake of simplicity all Subseres(1) beginning from all these causes may be grouped, direct or indirect, into three kinds, one is biotic, the others are climatic and edaphic.

(B) Climax

As already mentioned, every climax is the direct expression of the climatic, physiographic, and or edaphic factors, the climax, in its turn, reacting upon the cimate or the nature of the soil. So intimate are these relations that the climax must be regarded as the final test of a climate or nature of the soil rather than human response or the result of physical measurements.

(1) **Climatic** (Normal) **climax.**—Each succeeding generation of vegetation brings with it changes in composition and appearance, until the process of building up and breaking down reaches an equilibrium and the plant community likewise attains a stable composition. With the final stage completing the primary succession, the climax community is reached. Such climax

(1) A developmental series beginning an area secondarily bare as a result of the removal of the former communities.

type is known as a climatic or normal climax, which may not be identical over a whole tract of regions experiencing the same general climate, but may vary with micro-climate. Except possibly in certain mountain regions of northern or eastern Manchoukuo, the Russian Far East, and North China, it is doubtful if forest forms the climatic climax vegetations in any part of these regions.

(2) **Preclimax and postclimax.**—Exceptionally unfavourable sites, particularly those with low available moisture supplies, often carry a type more xerophytic than that corresponding to the general climate, and which is termed a preclimax, e. g. *Pinus Takahasii* NAKAI on the ridges or tops of rolling hills in the forests of northern Manchoukuo (Heiho (黑河) Province) and the Amur Prefecture in U. S. S. R.

Under the opposite condition of locally cooler or moister sites, a more mesophytic type is found, known as postclimax; in moist sites in the forests of eastern Manchoukuo will therefore be found *Larix olgensis* A. HENRY. Such preclimaxes and postclimaxes, though often indistinguishable from the related climatic climax, not rarely have characteristic features of their own.

(3) **Physiographic climax.**—On flat shores of estuaries we find extensive accumulations of river, or sea-borne silt, and elsewhere those of wind-blown sand, forming the characteristic "salt marshes" and sand dunes. Here, we see conditions for new successions constantly arising while, at the same time, the physiographic forces at work are constantly holding up successions in various stages, or throwing them back to an earlier stage. In such cases we have a physiographic climax, instead of the general climax, known as climatic climax. Not infrequently, we see in such situations a complex of small communities for the reason that the operation of physiographic factors instead of being uniform over the entire area, varies with place, so that local edaphic conditions differ widely in closely contiguous areas, with the likelihood of a given habitat being always swept away and replaced by another.

(4) **Edaphic climax.**—Because residual differences persist in site factors as the result of variation in soil texture, drainage, and extraneous supplies of moisture, the climax is not entirely uniform, climax dependent on soil peculiarities being known as edaphic climax.

II. Unit of plant community

(A) Flora and Vegetation

The actual plant covering of any region of the earth may be considered

from two distinct points of view. The list of the species of which the covering is composed is called its "flora", and should our interest be centred on these species as species, it is floristic interest. Should, on the other hand, our interest be the natural groupings of individual plants, whether these are groupings based on the Formation—system i. e., different kinds of forest, grassland, etc., or whether they are groupings derived from the Association—system which can be distinguished from the fact that the plant community is characterized mainly by "dominant"(1) species, then it is interest in "vegetation". In the first case, our main object is to assign all the individuals to their respective species (with their varieties and forms), and to learn all that is possible about these species, while in the second case, our chief object is to investigate the nature, relationships, and changes in the groupings of individuals that we call "vegetation" or plant communities.

The study of vegetation aims, and this has met with a large measure of success, to understand the conditions that determine the appearance and maintenance of different types of vegetation in different places, as well as to understand the laws that govern their development and change under the various habitat factors to which they are subject.

(B) Formation and Association

In any attempt to describe vegetation under the above heading, it is necessary to have some method by which the vegetation can be characterized and classified. For ecological purposes, there are two series of unit systems, one being based on its "physiognomy"(2) and habitat or environmental conditions (this is called "Formation"—system), the other being based on plant communities with their characterized dominant species and their physiognomy (this is called "Association"—system).

The entire vegetation of the world can be included ecologically in a comprehensive Formation—system. It is by the physiognomic characters of the vegetation, especially when correlated with some habitat, for example, topographic features, climatic factors, soil conditions, etc., that the investigator will find it easiest to recognize and record the chief types of Formation—system in the course of his journeys.

(1) That is, dominants are the chief constituents of a plant community. The visible unity of the climax is due primarily to the dominants or controlling species.

(2) Physiognomy, which express itself in the life forms of the dominants is the measure of the affected factors of habitat, excepting, however, their own inherited characteristics.

Thus a given community which falls under one unit of the Formation-system may be either a climax or a seral stage, or it may be the result of partial or complete destruction of one of these.

The other unit, association, proposed by FLAHAULT and SCHRÖTER, and adopted by the International Botanical Congress of 1910, held in Brussels, is defined as follows:—"An Association is a community of certain floristic composition, of uniform habitat conditions, and of uniform physiognomy"—a definition that has proved satisfactory, the exceptions being variations related to habitat conditions. Each Association owes its physiognomy to the dominants or characteristic species of the upper layers that control it. These dominants serve to provide the highest types of life form possible under the prevailing climate.

Each Association corresponds with the natural units of vegetation based on studies of climaxes and seral communities. It is necessary, however, to distinguish plants that are merely conspicuous or abundant from those that are actually dominant. By composition of an Association is meant not only the list of containing species, but includes also their dominance, sociability, constancy, fidelity, vitality, and periodicity. The constants and characteristics are the main features; they form the normal characteristic combination of species.

The habitat of an Association is primarily determined by climate, and secondarily by other factors, such as topography, soil, and the influence of animals. That is to say, outside a certain range of climate a given Association cannot exist, although from the mere fact that it is inside this range, it does not follow that it occupies the whole available territory, because various other causes prevent its doing so; or, stated in another way, certain other conditions have to be fulfilled before it can exist in a given spot. Besides the necessary edaphic and physiographic conditions, another condition has to be fulfilled, namely, the completion of the succession that leads up to the given Association. The Association may not yet be developed, although it will develop if the area is let alone. Another condition, also dependent on the "time factor", is that the dominant species, which determine the existence of the Association, may not have completed yet their geographical migrations, that is, they have occupied all the territory possible and will still further occupy (if unhindered by man) in the course of time.

Civilization brings in its train great destruction of natural communities by fire, by lumbering, and by clearance of land for cultivation. This has added

greatly to the difficulty of drawing exact boundaries between communities, such as Associations. Although the following map of the distribution ranges of the leading Associations (cf Fig. 49) cannot in any sense by claimed to be conclusive, yet it will serve to give the general outlines.

(C) Consociation and Sociation

(1) **Consociation.**—Consociation is a community in the Association-system ranking between Association and Sociation, typically constituted by a single dominant so far as the highest layer is concerned, while in the remaining layers there may be a certain amount of heterogeneity. As a matter of convenience, however, the term is also applied to areas in which other dominants are but sparingly present, for which reason it is difficult to ascertain what those dominants are that have no real share in the control of the community.

It is convenient to refer in the abstract to each major dominant of the Association as a Consociation, with, however, the reservation that it may occur more frequently in mixtures than by itself. In this sense it may be considered a unit of the Association—system, though the actual area of the latter should be regarded as divided into definite groupings of dominants or Sociation.

Consociation is plainly apparent over a considerable area only when the habitat factors, especially the water content of soil, fluctuate within the limits set by the requirements of a dominant. This is well illustrated by *Pinus densiflora*—Consociation in the lower part of the montane forest in the south-eastern part of the East Manchuria Region.

(2) **Sociation.**—Sociation is the elementary unit of the plant community of virtually uniform composition, with at least the dominant uniform in every layer, i. e., the concrete subdivision of the Association, characterized not by pure dominance but by the grouping of dominants. Except in the case of an Association consisting of several Consociations, rendering further subdivisions difficult, or in that of the seral stage, the entire area of the Association is composed of various Sociations, their number in a particular Association being also firstly determined, as a rule, by the number of subclimate or local climate within the general climate of the Association. A Sociation therefore corresponds to a particular local climate of real but small differences in temperature, humidity, and precipitation. In general, temperature and humidity appear to play directly the leading part in the development of Sociations, although in a certain area edaphic factors play the most decisive rôle.

III. Standard Formations

In constructing a synopsis of the world's Standard Formations, it seems best to follow up the larger unit of the Formation—system, and comprehend its ecology, morphology, and distribution. From this viewpoint a community, whether large or small, might usually be recognized as a part or a fragment of one of the following Standard Formations of the world. Of course, our present knowledge of the community orders of the world is still meagre, leaving much to be done in the future. Of these Formations, those that can be recognized in the regions under consideration are marked with small circles.

List of the world's Standard Formations(1)

1) Tropical rain evergreen Forest Formation.
2) Tropical semi-evergeen Forest Formation.
3) Tropical moist rain-green Forest Formation.
4) Tropical semi-dry rain-green Forest Formation.
5) Tropical semi-dry evergreen Forest Formation.
6) Tropical tall Herbage Wood Formation (somewhat seral in stage).
7) Tropical thorn Forest Formation.
8) Savanna Wood Formation (somewhat seral in stage).
9) Savanna Formation.
10) Hot Desert Formation.
11) Hot wander Waste Formation (somewhat seral in stage).
12) Mangrove Formation.
13) Hot Halophyte Formation.
14) Hot Acidophyte Formation.
15) Hot emersed Formation (somewhat seral in stage).
16) Hot submersed Formation.
17) Subtropical lighted evergreen Forest Formation.
18) Subtropical sclerophyllous Forest Formation.
19) Warm-temperate (moist) evergreen Forest Formation.

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(1) Respective explanation will be seen in the writer's following papers:

TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 971–980.

——: Units of the plant ecology and geography of the greater East-Asia (Japanese). Geography, **10** (1942) 1067–1082.

20) °Temperate (moist) summer-green Forest Formation.
21) Temperate (moist) needle-leaved Forest Formation.
22) °Temperate semi-dry needle-leaved Forest Formation.
23) °Temperate tall Herbage Wood Formation (somewhat seral in stage).
24) °Prairie Formation.
25) °Steppe Formation.
26) °Scrub Steppe Formation.
27) °Semi-cold Desert Formation.
28) °Semi-cold wander Waste Formation (somewhat seral in stage).
29) °Semi-cold Halophyte Formation.
30) Semi-cold Acidophyte Formation.
31) °Semi-cold emersed Formation (somewhat seral in stage).
32) °Semi-cold submersed Formation.
33) °Cold-temperate needle-leaved Forest Formation.
34) °Cold-temperate summer-green dwarf Forest Formation.
35) °Arctic or Alpine Scrub Formation.
36) °Arctic or Alpine Grassland Formation.
37) °Tundra Formation.
38) °Heath Formation.
39) °Hochmoor Formation.
40) °Summer-snow Waste Formation.

In order to emphasize the sociologic gradations of these Formations in the regions under consideration, their groupings and subdivisions will be seen in the following list, but Associations and their subdivisions are dealt with under the descriptions of respective Formations.

(A) Waste land Formation-group (Panformation).
- (1) Semi-cold Desert Formation.
- (2) Semi-cold wander Waste Formation.
- (3) Semi-cold Halophyte Formation.

(B) Grassland Formation-group (Panformation).
- (1) Steppe Formation.
  - (a) True Steppe Subformation.
  - (b) Low Steppe Subformation.
- (2) Scrub Steppe Formation.
- (3) Prairie Formation.
  - (a) True Prairie Subformation.
  - (b) Postclimax Prairie Subformation.
- (4) Temperate tall Herbage Wood Formation.

(C) Hydrophytes Formation-group (Panformation).
- (1) Semi-cold emersed Formation.
- (2) Semi-cold submersed Formation.

(D) Temperate Forest Formation-group (Panformation).
- (1) Temperate (moist) summer-green Forest Formation.
  - (a) Fringing and Terrace summer-green Forest Subformation.
  - (b) Montane summer-green Forest Subformation.
- (2) Temperate semi-dry needle-leaved Forest Formation.

(E) Boreal or Subalpine Forest Formation-group (Panformation).
- (1) Cold-temperate needle-leaved Forest Formation.
  - (a) Evergreen needle-leaved Forest Subformation.
  - (b) Summer-green needle-leaved Forest Subformation.
- (2) Cold-temperate summer-green dwarf Forest Formation.

(F) Arctic or Alpine Vegetation Formation-group (Panformation).
- (1) Arctic or Alpine Scrub Formation.
  - (a) Arctic or Alpine summer-green Scrub Subformation.
  - (b) Arctic or Alpine needle-leaved Scrub Subformation.
- (2) Arctic or Alpine Grassland Formation.
- (3) Tundra Formation.
- (4) Heath Formation.
- (5) Hochmoor Formation.
- (6) Summer-snow Waste Formation.

IV. Ecological Geo-botany

In studying the distribution of plant there are two subjects, namely the "Floristic Geo-botany" and the "Ecological Geo-botany". The first is the study of flora — the distribution of families, genera, species and varieties of plants, their origin and direction of migration, etc. — and the second is the study of vegetation. The second is subdivided into two phases, the distribution of the Formation—system and that of the Association—system.

The geographical distribution of the above-listed Standard Formations in the regions under consideration is shown in Fig. 31 (cf P. 539). Owing partly to the small scale of its map and partly to incompleteness of the writer's field investigations in the regions visited, the map is inevitably somewhat diagrammatic, although it brings out the general outline of their distributions and the main features of their mutual situations which will be referred to in the succeeding chapter.

While the ecological regions based on the geographical distribution of the

leading Associations in the regions under consideration is found in Fig. 49.

Instead of these longitudinal divisions mentioned above, the vegetations vary also in accordance with the difference of elevation presenting the typical feature of vertical distribution of Formations, especially on such high mountains as Wutai-Shan or Hakutosan, with an exception of the lowest regions which have long been reclaimed in various ways and the natural physiognomy of vegetations very much disturbed. This zone which may be termed the "colline zone"(1) extends upwards to an altitude on the average about 500–600 m above sea-level comprising Fringing and Terrace summer-green Forest Subformation. The zone above this, i. e. the montane zone, reaches at its highest part to about 900–1100 m on the average. Numerous kinds of broad-leaved summer-green trees, which are representatives of Montane summer-green Forest Subformation, and several species of conifers, which are members of Temperate semi-dry needle-leaved Forest Formation, occur in this zone. The presence of these conifers here, often in great quantities, appears to be inappropriate to call this zone "broad-leaved or deciduous zone" though both of these names have frequently been used.

Following this comes the subalpine zone. In this zone, as a rule, occur the conifers belonging to Cold-temperate needle-leaved Forest Formation predominate, though several species of broad-leaved trees peculiar to this zone, such as representatives of Cold-temperate summer-green dwarf Forest Formation, occur as well. Moreover, the conifers growing in the lower parts of this zone (from 800–1100 m to 1500–1600 m) are occasionally somewhat different from that of upper parts (from 1500–1600 m to 1800–2200 m). In the upper parts of this zone, the height of forest trees gradually diminishes as going upwards, and when the altitude of somewhere about 1800–2200 m is reached, the trees become dwarfed and bushy in habit, and clearly show a transition to the alpine zone.

SCHRÖTER(2) and TAKEDA(3) recognized on the Alps and on the high mountains of Japan respectively an intermediate region between the subalpine and alpine zones; SCHRÖTER named it the "Kampfgürtel", where he found isolated trees more or less dwarfed. These trees are sometimes found to be conifers belonging to Cold-temperate needle-leaved Forest Fomation and sometimes the members of Cold-temperate summer-green dwarf Forest Forma-

(1) The zone of low hills or mountain-feet.
(2) SCHRÖTER, C.: Das Pflanzenleben der Alpen. (1926).
(3) TAKEDA, H.: Alpine flowers of Japan. (1938).

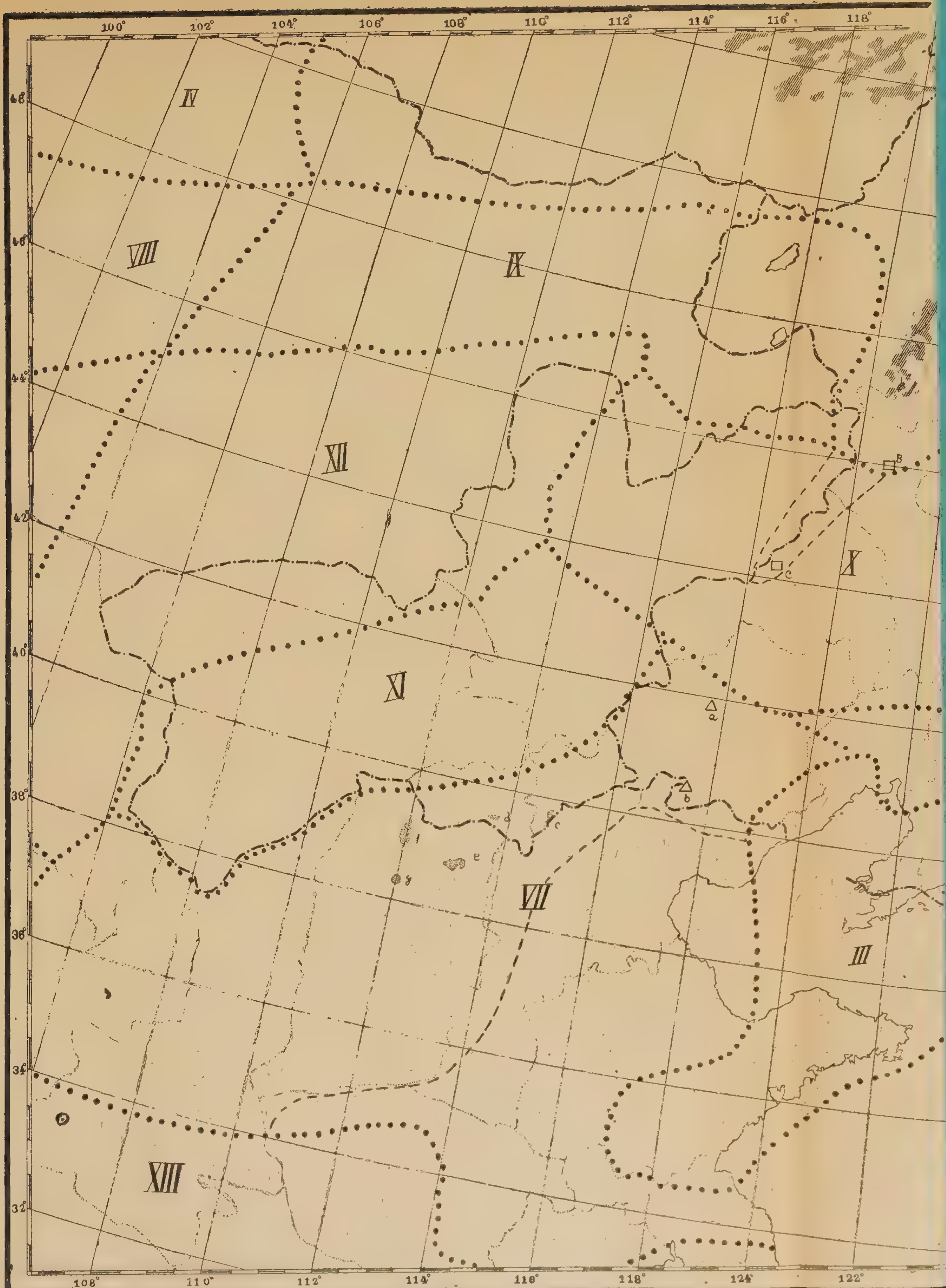
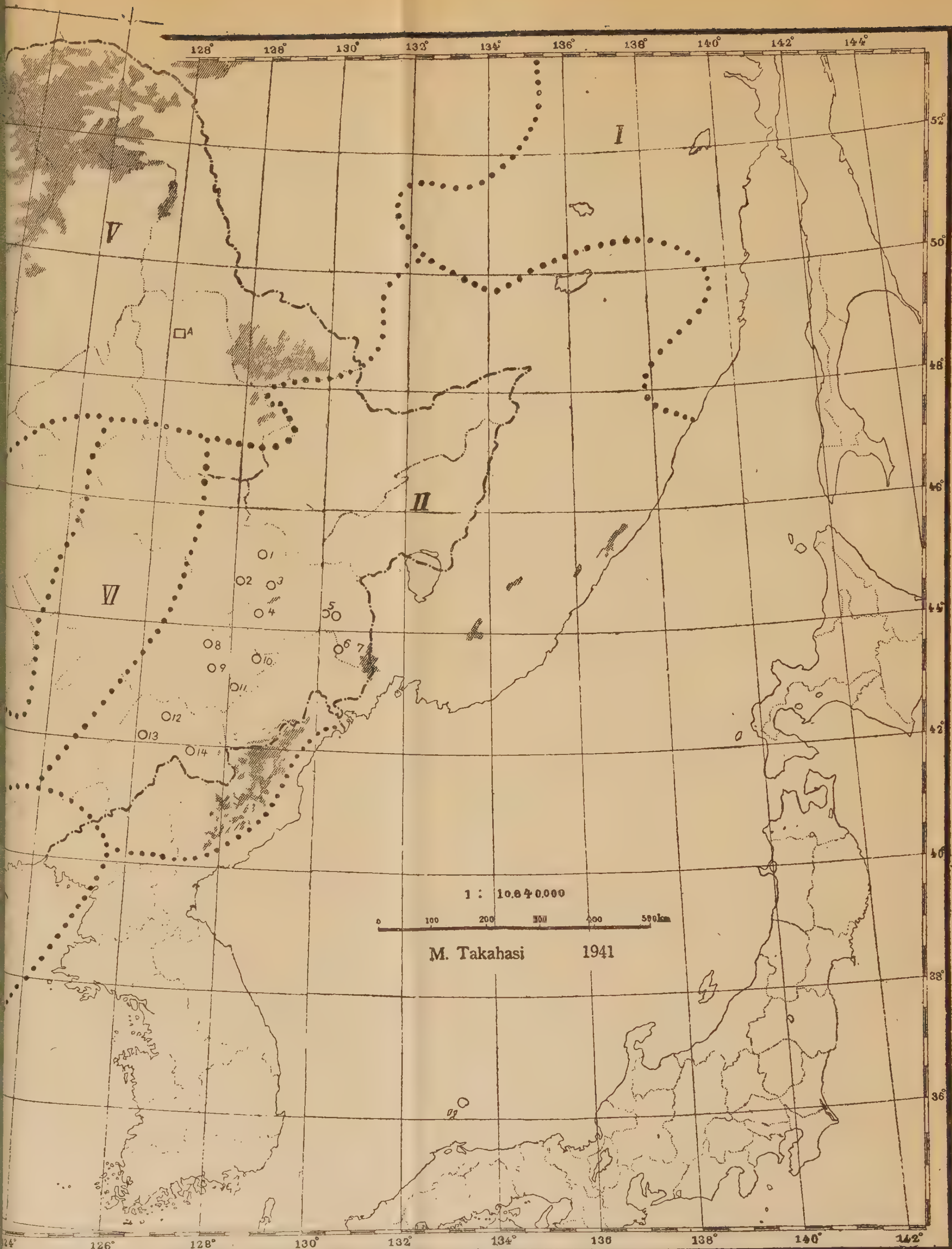


Fig. 49. Map of ecological regions in Northern East-Asia based on the distribution ranges of the leading A
V. Davuria Region. VI. Manchurian Plain Region. VII. North China Region. VIII. Western North Mong
XII. Central Mongolia Region. XIII. Great Szechwan (四川) Region.



ssociations. I. Okhotsuk Region. II. East Manchuria Region. III. Pohai (渤海) Region. IV. Central Siberia Region.
lia Region. IX. Eastern North Mongolia Region. X. East Mongolia Region. XI. Eastern South Mongolia Region.

tion. They appear in the higher parts of the subalpine region and grow still higher up in the lower part of the alpine zone as well intermingling with the members of Arctic or Alpine Scrub Formation which rarely occur on Mts. Wutai-Shan.

V. Formations in the regions under consideration

(A) Waste land Formation-group (Panformation)

(Semi-cold Desert, Semi-cold wander Waste, and Semi-cold Halophyte Formations)

(1) **Semi-cold Desert Formation.**—In the popular mind, a "desert" is a vast sandy waste, typified by pictures of the Sahara in elementary geographies—an idea perpetuated by earlier misconceptions regarding the Gobi Desert, the greater parts of which are actually a kind of steppe or sand dunes and plains. The scientist's usage has naturally been more definite, based in part at least on the physical factors of rainfall and temperature, but even he has sometimes been misled by climatic relicts that have assumed new rôles as indicators of disturbance.

In geographic parlance, a desert is a region which because of scarcity of rainfall, has little or no vegetation, and is consequently scantily populated; while, ecologically it is an area marked by extremely open vegetation with a few peculiar species or by its absence according to place or time, with low rainfall and high evaporation as causal factors. As a consequence, an accurate and practicable definition of the term must evidently be based primarily upon vegetation and rainfall, with some consideration of the animals, and of temperature during the growing season, at any rate. But, strange to say, the term desert is often loosely used by ecologists and geographers alike. In these cases, the desert so-called, fails to comply with the full meaning it should convey, even the vast areas of sand dunes and plains of the inner continent being a true desert in only a part of the areas concerned. The most decisive test is afforded by tracing the inner boundary of a Steppe Formation (in the regions under consideration) or a Savanna Formation (in the subtropical regions). Obviously, such a delimitation is intimately correlated with the data of rainfall, or better still, rainfall / evaporation,[1] indices of aridity,[2] etc.,

(1) THORNTHWAITE, C. W.: The climates of N. America according to a new classification. Geogr. Rev., **21** (1931) 633.

(2) MARTONNE, EMM. de: Aréisme et indice d'aridité. Comptes Rendus, **182** (1926) 1935.

——: Regions of interior basin drainage. Geogr. Rev. **17** (1927) 397.

assuming that they have been recorded for a number of years at various localities. Notwithstanding all this, it is clear that the boundary of Desert Formation itself cannot be sharply demarcated, all that will be possible being a fair approximation. Overgrazing is another difficulty that will present itself.

At any rate, the limits of Semi-cold Desert and Steppe Formations must be determined by the density of the vegetation in the most characteristic Associations, and in order to do so successfully, they must be sought for most diligently in the wet phase of the cycle, when they are most in evidence. Moreover, as already referred to in the section on climatic factors. The isohyetals generally serve as an index, although only roughly, particularly when they are based upon relatively few and recent observations including even those of a speculative nature, in such localities like the inner part of the regions under consideration.

At the same time, these criteria as determined by the density of vegetation have the merit that they serve not only as practicable base for circumscribing a Semi-cold Desert Formation, but also Waste land Formation-group at large, as sometimes for other Formations.

A plant community of true desert character is sometimes supposed roughly to have average bare ground occupying more than half the total space, but this idea, considering the various life-forms growing there, is not satisfactory in every case. The writer's criteria of the density that seem to be characteristic of a true desert, contain two main components: one expressed by the percentage of total basal area of a vegetation (in the case of grassland a meter quadrate being always used for these purposes), while in a true desert it seldom exceeds 2.5 per cent. The other is expressed by the percentage of the total projection area of the vegetation (for this purpose, the camera, which has been used for a number of years, promises to become a general method; cf Figs. 50 to 53), while a true desert would have scarcely more than 25 per cent of this value, regardless of the life-forms of plants contained. Should these two kinds of components not agree, it may well be expected that the denser delimitation will be the more reliable one to consider.

On the other hand, the characters of the growing plants, especially those of the dominant species, as already shown in the section on "Indicator", have also marked features in any kind of plant community. Within desert borders, the perennial grasses are of the first importance, although perennial forbs and woody plants also have much significance, whereas the annual grasses receive

Fig. 50. A density corresponding to True Steppe Subformation
(face P. 578). (M. TAKAHASI)

Fig. 51. A density corresponding to Low Steppe Subformation
(face P. 578). (M. TAKAHASI)

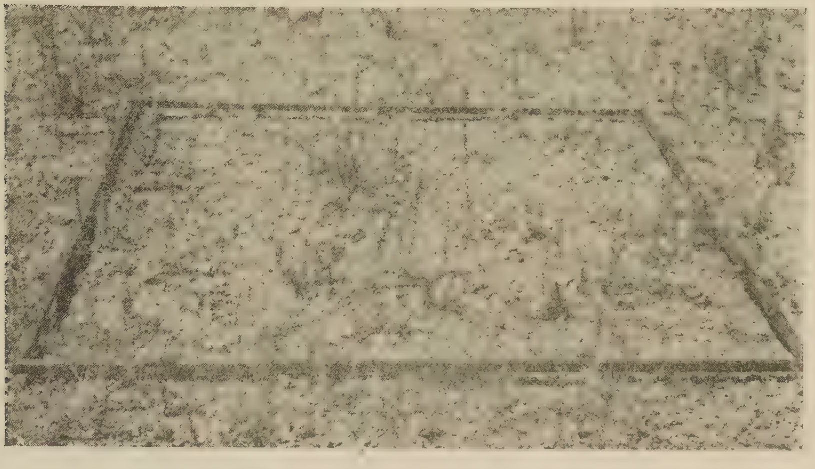


Fig. 52. Minimum density corresponing to Low Steppe Subformation, that is maximum limit of Desert Formation (face P. 578).

(M. TAKAHASI)

Fig. 53. A density corresponding to Desert Formation (face P. 578)
(M. TAKAHASI)

small consideration, except for the group of desert endemics, such as ephemerals.

Furthermore, Hydrophytes and Halophytes not only have the peculiar ability to migrate but they also evade climatic control in varying degrees. Their presence, therefore, is not of much significance.

Next to the perennial grasses, the perennial forbs are of major importance. Like the grasses, this group is divisible into those still persisting in the desert and those that have disappeared from it. Because of their higher water requirements and more direct exposure to the influence of a changing climate, trees are very few. In the regions under consideration only four species of this group occur in the desert, namely *Salix mongolica* SIUZ. (cf Fig. 54), *Salix Kochiana* TRAUTV., *Populus Simonii* CARR. and *Ulmus pumila* L. The first two are usually shrubs, but all are confined to valleys, washes, or sand dunes with higher watercontent than that of the desert proper. The typical dominants in Semi-cold Desert Formation are *Caragana pygmaea* DC. and *Salicornia ambigua* MICHX. (cf Fig. 55), both of which form their respective Sociations, although they also distribute over much wider areas than that in which they are climax. Tracing them step by step on dry alkali spots, they have spread extensively, replacing the vanishing grasses. In the regions under consideration, they are found from western Baruga to the Sinkiang (新疆) but, in all these vast stretches, they are climax only in the desert areas.

Within desert borders, the perennials or annuals, which are generally found as dominants of the original climax in Steppe Formation, have persisted only as the result of local protection, maintaining themselves to some extent in shallow washes, on sandy soils, or on rocky or northerly slopes, wherever edaphic compensation for climatic drought is to be found. Thus, in a desert, as in grassland generally, such edaphic compensation for climatic dryness is more or less adequate, if only occasional, and the organisms concerned cannot be directly used as climatic indicators.

(2) **Semi-cold wander Waste Formation.**—As the embryonic dunes grow larger and higher, conditions for sand accumulation become more favourable. Once the dunes are formed, then the wind begins to reshape them gradually and the dunes start to wander, forming a special seral habitat of wander waste. The wind either blows loosened sand into the dunes or takes the sand out of them; such dunes usually have a long gentle slope on the windward side, but a steep one on the leeward side (cf Fig. 56). The wind sweeps up the windward slope carrying or rolling the sand along with it

until the crest is reached, when the sand then rolls down the leeward side. Thus the dune, as a whole, is shifted forward by the wind only a few centimeters or, at most, a few meters a year, but always forward. Sometime the old vegetation is entirely covered with sand, but their remains may be uncovered with the advance of the dunes.

The main sand dune regions, where wander wastes usually prevail, lie on the south and west side of Dalainor, on the south side of Hsilamulun-Ho (西喇木倫河), in the Ordos, in the Alashan, in the wild and fierce Takla Makan, and here and there in Dzungaria.

It seems difficult for vegetation to capture a rapidly moving dune, although special xerophytic pioneers may grow upon them. Some of these grasses and shrubs propagate extensively by means of rhizomes, e. g., *Agriophyllum arenarium* BIEB. and *Stipa caduciseta* KITAG. (cf Fig. 57). All plants growing there have great powers of vertical elongation as the sand piles up about them.

Agriophyllum arenarium—Sociation, *Stipa caduciseta*—Sociation, *Artemisia Halodendron*—Sociation, and *Olgaea leucophylla*—Sociation are common in the present habitat, but the last two Sociations are also found on the fixed dunes or sandy soils that present a denser appearance, whereas the first two Sociations nerver show the slightest tendency to invade even the surrounding fixed dunes. *Pugionium cornutum*—Sociation has also the same tendency. This Sociation was first discovered by the writer in East-Asia (cf Fig. 58).

(3) **Semi-cold Halophyte Formation.**—In dry climates the paucity of precipitation decreases leaching and gives the conditions for the accumulation of easily soluble salts which are injurious to ordinary plants. Thus, as already referred, saline or alkaline areas are characterized by relatively few species that form a very open cover of vegetation. In these places, the boundaries separating the different communities are often very abrupt and distinct. The most remarkable feature here is the formation of concentric vegetation or vegetation in concentric circles with a salt marsh or lake as center. This is because the salt accumulation in soil undergoes considerable local changes. As one of the most typical examples, the writer recognized a salty marsh near West-Sonitto (西蘇尼特) having the following zones:

1st zone: *Salicornia herbacea*—Sociation.

2nd zone: *Suaeda corniculata*—*S. heteroptera*—Sociation; comprising. *S. glauca* BUNGE.

3rd zone: *Obione sibirica*—*Atriplex Gmelini*—Sociation; comprising partly

Fig. 54. *Salix mongolica* SIUZ. growing on a sand dune (face P. 583). (M. TAKAHASI)

Fig. 55. *Salicornia ambigua* MICHX. growing on an alkali spot (face P. 583). (M. TAKAHASI)

Fig. 56. Distant view of Semi-cold wander Waste Formation in the southern Mongolia Region (face P. 583). (M. TAKAHASI)

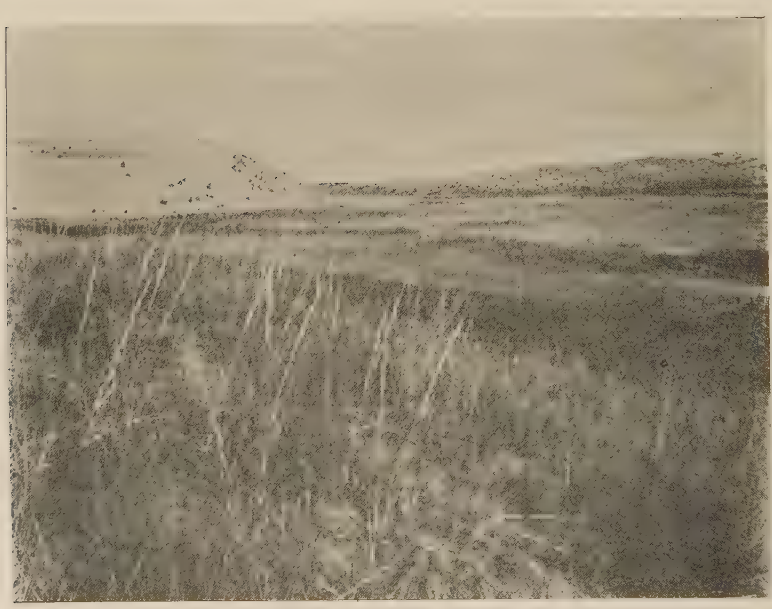


Fig. 57. *Stipa caduciseta*—Sociation on a sand dune (face P. 584). (M. TAKAHASI)

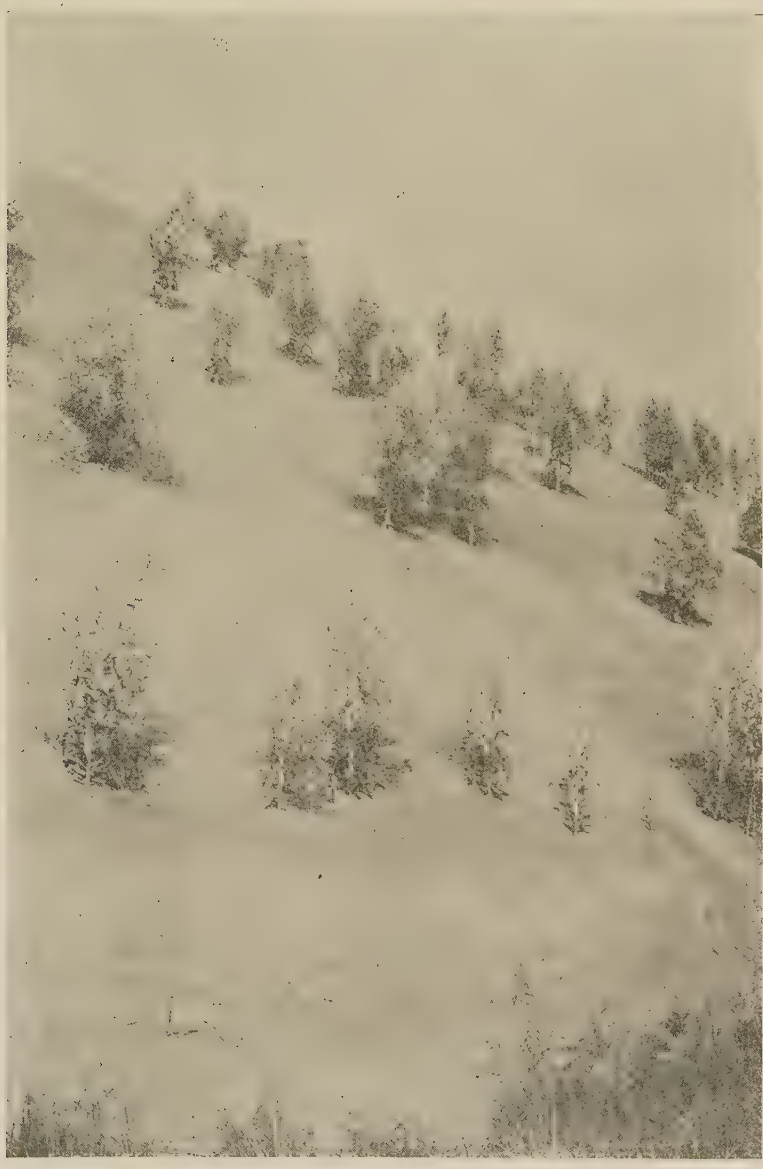


Fig. 58. *Pugionium cornutum*—Sociation on a sand dune (face P. 584).
(M. TAKAHASI)

Fig. 60. Distant view of True Steppe Subformation in the southern Mongolia Region (face P. 590). (M. TAKAHASI)

Fig. 61. The boundary between True and Low Steppe Subformations, i. e., the limitation of reasonable dry farming (face P. 590). (M. TAKAHASI)

Atropis distans GRISB., *Luzula capitata* NAKAI, or *Polygonum aviculare* L.

4th zone: *Salicornia ambigua*—Sociation; comprising partly *Limonium aureum* H. O. KUNTZE or *Saussurea runcinata* DC.

5th zone: *Kalidium gracile*—Sociation.
Nitraria Schroberi—Sociation.

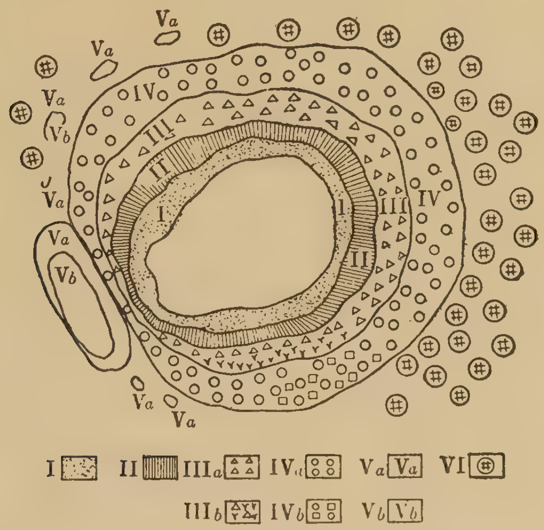


Fig. 59. Vegetation in concentric circles with a salt marsh as a center. (M. TAKAHASI)

I. *Salicornia herbacea*—Sociation.
II. *Suaeda corniculata*—*S. heteroptera*—Sociation.
IIIa. *Obione sibirica*—*Atriplex Gmelini*—Sociation.
IIIb. IIIa—Sociation, with *Atropis distans*, *Luzula capitata* and *Polygonum aviculare* mixed.
IVa. *Salicornia ambigua*—Sociation.
IVb. IVa—Sociation, with *Limonium aureum* and *Saussurea runcinata* mixed.
Va. *Kalidium graçile*—Sociation.
Vb. *Nitraria Schroberi*—Sociation.
VI. Surrounding vegetation, e. g., *Lasiagrostis splendens*—Sociation.

This salty marsh, which shows pH 8.0, exhibits a strong Cl-ion reaction, and *Salicornia herbacea*—Sociation being intimately related to the Cl-ion reaction, should a certain salt marsh lack or have only a little of this ion, it invariably lacks the first zone. Compared with these saline areas, on the other hand, some marshes or ponds whose pH exceeds 8.7 appear very simple, having only two or three zones as follows:

1st zone: *Heleocharis intersita*—Sociation, *Pleuropleropyrum sibiricum*—Sociation, or *Carex duriuscula*—Sociation; these are sometimes intermingled.

2nd zone: *Saussurea glomerata*—Sociation; sometimes comprising *Butomus umbellatus* L. or *Beckmannia Syzigachne* FERN.

3rd zone: *Ranunculus ruthenicus*—*Ixeris stenoma*—Sociation; mostly comprising *Triglochin maritimum* L.

(B) **Grassland Formation-group** (Panformation)

(Steppe, Scrub Steppe, Prairie, and Temperate tall herbage Wood Formations)

(1) **Steppe Formation.** — The vegetation of the wide grasslands extending from the feet of the Trans-baicalian, Khingan (興安), East Manchuria, North China, and other surrounding mountains inward to the margin of the Gobi Desert are not everywhere uniform. No doubt, those in the northern Outermongolia, central and western Manchoukuo, and southern Innermongolia, differ more or less in species and types. In Grassland Formations, the plant types as a whole, are clearly distinct from communities in Desert Formation or Montane Forest Formation-group. Grassland Formation-group moreover, consists of two main parts, Steppe Formation and Prairie Formation; the former of which may be well recognized as broad beltwise grassland areas surrounding Semi-cold Desert Formation as a center, the latter circumscribing the still outer sides of these two Formations (cf Fig. 31. Formations in Northern East-Asia).

The differences in the two grassland Formations are mainly those in the quantities of soil moisture from rainfall and the length of time during which the soil moisture is available. The diminishing relative humidity as one goes innerward toward the Mongolian Plateau is another important factor. Differences in soil structure and in its components are also pronounced. These factors, which have so largely determined the type of grassland, strikingly influence development or both root and shoot. From this viewpoint, Steppe Formation might be subdivided into two Subformations, True Steppe (cf Fig. 60) and Low Steppe Subformations (cf Fig. 61). In either case, the Subformation is a stage in the climatic climax vegetation on drier sites, excepting those few that are too dry for certain trees that might colonize them. The major difference between True and Low Steppe Subformations is indicated by changes in dominants and in the height and density of growing vegetations, as a whole. That is, the taller and more mesophytic species in the former are replaced by those of lower stature and greater ability to resist drought in the latter.

(a) **True Steppe Subformation.** The greater part of the Subformation consists of mid grasses.(1) Originally, they covered the climax areas to the exclusion of other grasses, the tall ones being confined to the neighbourhood of fresh-water ponds or marshes, ravines, and the bases of slopes. For the most part, these mid grasses assume the bunch form, except where there is a tendency to develop short rhizomes by means of which they root to depths in the soil. Even in the drier parts, and however severe the early spring drought, the soil is usually moist a few meters deep — conditions that favour the development of deeply rooted species in large number.

At any rate, a dense stand of mid grasses points to possibilities of crop production. The boundary between True and Low Steppe Subformations thus approximately demarcates reasonable dry-farming.

The Subformation comprises the following Associations and Sociations:

(i) ***Aneurolepidium chinense*—Association.**

This Association, the most characteristic one, and which prevails throughout the area, might be subdivided as follows:

a) *Aneurolepidium chinense*—Sociation.
b) *Chloris virgata*—*Setaria viridis*—Sociation.
c) *Bromus inermis*—*Trisetum sibiricum*—Sociation.

(ii) ***Artemisia sibirica*—Association.**

This Association occurs on somewhat drier site and might be subdivided as follows:

a) *Artemisia sibirica*—Sociation.
b) *Artemisia sacrorum*—*A. anethifolia*—Sociation.
c) *Artemisia annua*—*Galium verum*—Sociation. (somewhat seral in stage)
d) *Aster altaicus*—*Gentiana decumbens*—Sociation.

(iii) ***Scabiosa comosa*—*Delphinium grandiflorum* (var. *chinense*)—Association.**

a) *Scabiosa comosa*—*Delphinium grandiflorum* (var. *chinense*)—Sociation.
b) *Swertia chinensis*—*Patrinia scabra*—Sociation.
c) *Scutellaria baicalensis*—*Thalictrum petaloideum*—Sociation.

(iv) Besides above mentioned Associations, under special edaphic conditions several Sociations are found.

1) As preclimaxes derived from Low Steppe Subformation:
a) *Artemisia frigida*—Sociation.
b) *Stipa baicalensis*—Sociation.

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(1) The low grasses are less than 0.3 meters high, the mid grasses range from 0.3 to 1 meter, while the tall ones reach 1.5 to 2 meters and even more.

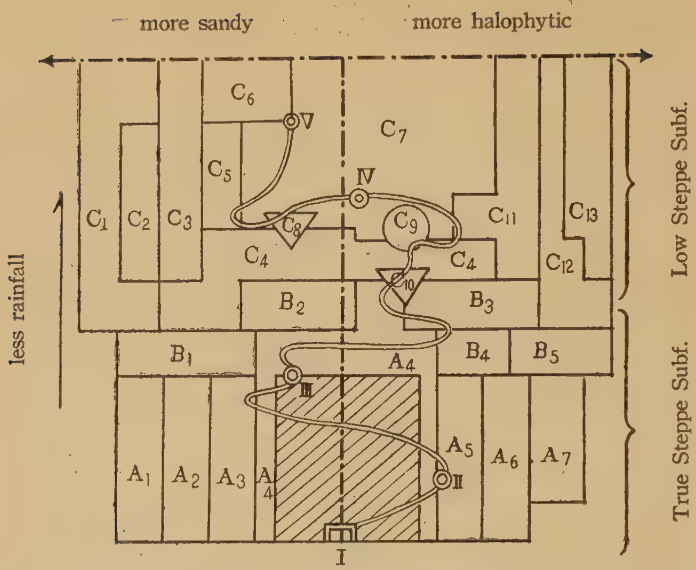

Fig. 62. Diagram illustrating relationships of soil grain (sand percentage) and moisture conditions to plant communities from Kalgan N. N. W. to the mergin of the Gobi Desert. Not drawn to scale. Total distance, about 300 km. This is applicable to a very large part of the steppe region in Innermongolia. (M. TAKAHASI)

climax or seral stage, ▽ preclimax, ○ postclimax, under cultivation, kalgan—Ulan Bator high way (張庫街道) and its branch.

I. Kalgan (張家口), II. Changpeh (張北), III. Tunhwa (德化), IV. West-Sonitto (西蘇尼特), V. East-Sonitto (東蘇尼特).

A_1. *Artemisia sacrorum—A. anethifolia*—Sociation.
A_2. *Aster altaicus—Gentiana decumbens*—Sociation.
A_3. *Scabiosa comosa—Delphinium grandifloum* (var. *chinense*)—Sociation.
A_4. *Aneurolepidium chinense*—Sociation.
A_5. *Sanguisorba obtusa—Leonurus sibiricus*—Sociation.
A_6. *Bromus inermis—Trisetum sibiricum*—Sociation.
A_7. *Iris Pallassii—I. dichotoma*—Sociation.
B_1. *Chloris virgata—Setaria viridis*—Sociation.
B_2. *Pennisetum flaccidum*—Sociation.
B_3. *Artemisia frigida*—Sociation.
B_4. *Polygonum aviculare*—Sociation.
B_5. *Iris Pallasii*—Sociation.
C_1. *Agriophyllum arenarium*—Sociation.
C_2. *Stipa caduciseta*—Sociation.
C_3. *Artemisia Halodendron*—Sociation.
C_4. *Stipa baicalensis*—Sociation.
C_5. *Caragana microphylla* (var. *daurica*)—Sociation.
C_6. *Caragana pygmaea*—Sociation.
C_7. ***Artemisia pectinata*—Association.**
C_8. *Glycyrrhiza uralensis*—Sociation.
C_9. *Lasiagrostis splendens*—Sociation.
C_{10}. *Ephedra distachya*—Sociation.
C_{11}. *Nitraria Schoberi—Reaumuria soongorica*—Sociation.
C_{12}. *Obione sibirica—Atriplex Gmelini*—Sociation.
C_{13}. *Salicornia herbacea*—Sociation.

Fig. 63. Distant view of Low Steppe Subformation in the southern Mongolia Region (face P. 593). (M. TAKAHASI)

Fig. 64. *Stipa baicalensis*—Sociation (face P. 593). (M. TAKAHASI)

Fig. 65. *Artemisia pectinata*—Sociation (face P. 593).
(M. TAKAHASI)

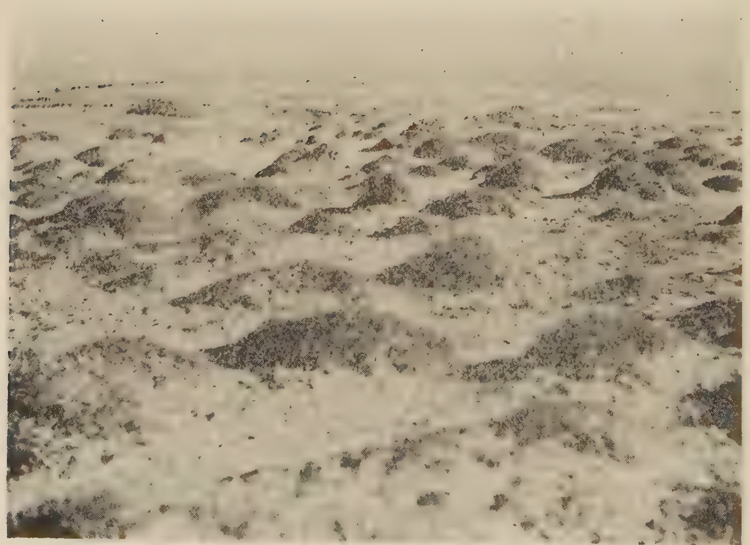

Fig. 66. *Artemisia frigida—Thymus asiaticus*—Sociation (face P. 596)
(M. TAKAHASI)

2) As postclimax derived from Prairie Formation:
Sanguisorba obtusa—Leonurus sibiricus—Sociation; comprising *Hemerocallis Middendorfii* TRAUTV., *Trifolium lupinaster* L., *Hypericum Ascyron* L., *Erodium Stephanianum* WILLD., *Lilium tenuifolium* FISCH., *Gymnadenia conopsea* BROWN., *Herminium Monorchis* R. BROWN, etc.

3) On somewhat salty places:
a) *Iris Pallasii—I. dichotoma*—Sociation.
b) *Puccinellia tenuiflora*—Sociation.

(b) **Low Steppe Subformation.** This Subformation serves to connect True Steppe Subformation with Desert Formation, the name being derived from its dwarfed nature (cf Fig. 63). But a few mid grasses sometimes form the upper story, while short grasses always prevail. The presence of short grasses is in accord with the general reduction in rainfall and high evaporating power. In the regions under consideration, records for which, however, are meagre, it is supposed that the rainfall ranges from 250 to 350 mm; with corresponding restricted soil penetration, the last determining the depth to which roots may grow, these in turn fixing the limit to which leached salts accumulate to form a more or less definite carbonate layer. The latter, which usually occurs at a depth of 40 to 70 cm and may be from 20 to 50 cm thick, while below it the subsoil is dry. Even in this Subformation, mid grasses, e. g., *Aneurolepidium chinensis* KITAG. and *Arundinella hirta* var. *ciliata* KOIDZ. in particular, are still sometimes found, although as a rule in reduced forms. Dwarf xerophytic undershrubs(1) with white hairy leaves also play an important rôle, especially various species of *Kochia*, *Eurotia* and *Artemisia*.(2)

The Subformation comprises the following Associations and Sociations:

(i) ***Stipa baicalensis*—Association.**
a) *Stipa baicalensis*—Sociation (cf Fig. 64).
b) *Pennisetum flaccidum*—Sociation.

(ii) ***Artemisia pectinata*—Association.**
a) *Artemisia pectinata*—Sociation (cf Fig. 65).
b) *Artemisia pectinata—Allium anisopodium*—Sociation.

(iii) ***Artemisia frigida*—Association.**

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(1) A partially herbaceous plant, the ends of the branches dying during the unfavourable season.

(2) *Kochia prostrata* SCHRAD., *K. Scoparia* SCHRAD., *K. Sieversiana* MEY. C. A., *Eurotia arborescens* LOS.-LOSIN., *E. prostrata* LOS.-LOSIN., *Bassia dasyphylla* KTZE., *Artemisia maritima* L., etc.

a) *Artemisia frigida*—Sociation.

b) *Artemisia frigida—Thymus asiaticus*—Sociation (cf Fig. 66).

(iv) Besides above illustrated Associations, under special edaphic conditions several Sociations are recognized.

1) As a postclimax around lakes or marshes, and the bases of slopes: *Lasiagrostis splendens*—Sociation.

2) On the comparatively fixed part of sand dunes: *Artemisia Halodendron*—Sociation.

(2) **Scrub Steppe Formation.**—Since this Formation is more or less intermediate in character between Semi-cold Desert Formation and True Steppe Subformation, it resembles Low Steppe Formation, especially in its climatic relations. It grows in rather sandy or gravelly areas that have deeper water tables than those of Low Steppe Subformation. The dominants are bushy shrubs; usually 0.5 to 2 meters high, with the ability to produce root sprouts, to which they owe the many-stemmed habit as well as much of their dominance. In this Formation the single communities sometimes extend for many kilometers and form striking physiognomy.

The Formation comprises the following Associations and Sociations:

(i) ***Caragana microphylla* var. *daurica—C. pygmaea*—Association.**

a) *Caragana microphylla* var. *daurica*—Sociation.

b) *Caragana pygmaea*—Sociation.

Although these Sociations are both typical and prevalent in the drier sites, the latter is more xeromorphic than the former.

(ii) Besides above mentioned Associations, under special edaphic conditions several Sociations are found.

1) Growing in well drained loamy soils:

a) *Glycyrrhiza uralensis*—Sociation.

b) *Ephedra distachya*—Sociation.

2) On salty areas:

a) *Nitraria Schoberi—Reaumuria soongorica*—Sociation.

b) *Salicornia ambigua*—Sociation.

3) On dry salty areas:

a) *Anabasis aphylla*—Sociation.

b) *Zygophyllum xanthoxylum*—Sociation (cf Fig. 67).

(3) **Prairie Formation.**—This Formation owes its character to the dominant grasses. Although the woody plants are few in species, they sometimes

Fig. 67. *Zygophyllum xanthoxylum*—Sociation (face P. 596).
(M. TAKAHASI)

Fig. 68. Distant view of Prairie Formation (face P. 599).
(M. TAKAHASI)

Fig. 69. *Phragmites communis*—Association in Jehol (face P. 600).
(M. TAKAHASI)

cover wide areas of climatic grassland (cf Fig. 68), shrubs being abundant; and appear to be the controlling plants, notwithstanding their low stature. Even here, careful investigation may sometimes show that their dominance is the consequence of disturbance by man or domestic animals; which disturbance has often been mistaken for true climax.

The Formation, at any rate, occupies wide limits between True Steppe Subformation and Montane Forest Formation-group or Temperate tall Herbage Wood Formation (the last two communities to be referred to later). The transition from True Steppe Subformation to Prairie Formation, however, is very gradual and the corresponding ecotone(1) usually broad. The sharpest limit is set by the disappearance of *Stipa baicalensis*—Sociation and *Lasiagrostis splendens*—Sociation, and in addition by the appearance of *Miscanthus sacchariflorus*—Sociation and *Miscanthus sinensis*—Sociation. In the western part of the Manchurian Plain Region, the relation is further disturbed by the extensive sand hills, in which the high available water content favours(2) a postclimax of tall grasses far beyond their proper climatic range. *Pennisetum flaccidum*—Sociation and *Bromus inermis*—*Trisetum sibiricum*—Sociation persist over much of the dry sandy soils, *Phragmites communis*—Association, at the same time, occupying the area with more available water.

What is worse, cultivation has almost completely removed the Formation from most of its area, and its original limits have been pieced together only during the past decade from the numerous relatively small and scattered fragments. Because of these circumstances, the exact limits of the Formation can never be set, and the boundary lines drawn on the map can be no more than general approximations.

From the viewpoint of the height and density of growing vegetation and the change in dominants, this Formation might be subdivided into two Subformations, True Prairie and Postclimax Prairie Subformations; that is, the taller and more hygrophic species in the latter are replaced by those of mid grass and mesic species in the former.

(a) **True Prairie Subformation.** This Subformation is not uniform throughout its vast extent; *Arundinella hirta* (var. *ciliata*)—*Spodiopogon sibiricus*—Association, however, is most prevalent, comprising the following Associations and Sociations.

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(1) Ecotone means mixed communities formed by the over-lapping of adjoining communities in the transition areas.

(2) This question has been raised in the section under "Soil water."

(i) ***Arundinella hirta* (var. *ciliata*)—*Spodiopogon sibiricus*—Association.**

a) *Arundinella hirta* (var. *ciliata*)—*Spodiopogon sibiricus*—Sociation.

b) *Calamagrostis Epigeios*—Sociation.

c) *Miscanthus sacchariflorus*—Sociation.

d) *Setaria viridis*—*Digitaria Ischaemum*—Sociation.

(ii) ***Patrinia scabiosaefolia*—*Paeonia albiflora*—Association.**

a) *Patrinia scabiosaefolia*—*Paeonia albiflora*—Sociation.

b) *Artemisia japonica* (var. *manchurica*)—*Vicia amoena* (var. *oblongifolia*)—Sociation.

c) *Potentilla fragarioides* (var. *Sprengeliana*)—*Trifolium lupinaster*—Sociation.

(b) **Postclimax Prairie Subformation.** This Subformation, which is a kind of postclimax of True Prairie Subformation, comprises tall grasses, often 1.0 to 2.5 meters high. In most of the areas the major Associations are *Calamagrostis Langsdorffii*—Association and *Phragmites communis*—Association in the north; and *Phragmites longivalvis*—Association in the south. The latter two Associations usually overlap Semi-cold emersed Formation. But these are also found between sand hills and along dry river beds.

(i) ***Calamagrostis Langsdorffii*—Association.**

a) *Calamagrostis Langsdorffii*—*Sanguisorba tenuifolia*—Sociation.

b) *Calamagrostis Langsdorffii*—*Thelypteris palustris*—Sociation.

c) *Calamagrostis Langsdorffii*—*Eriophorum polystachyon*—Sociation.

(ii) ***Phragmites communis*—Association** (cf Fig. 69).

(iii) ***Phragmites longivalvis*—Association.**

(4) **Temperate tall Herbage Wood Formation.**—The grasslands of the higher alluvium are usually traceable to destruction of preexisting forest by human settlement and to the prevention of recolonization by fire, grazing, and deteriorated soil conditions, whence Formations, such as these plant communities, are known as a seral stage, serving to connect Prairie Formation with Montane Forest Formation-group. The most familiar of these lies within Temperate moist summer-green Forest Formation or forms a narrow interrupted belt along its margin. It is a preclimax to Montane Forest Formation-group which, at the same time, may serve as a subclimax in its development. But the communities of this Formation are virtually identical with those of True Prairie Formation, reinforced by additions from the deciduous forest in it.

(C) **Hydrophyte Formation-group** (Panformation)

(Semi-cold emersed and Semi-cold submersed Formations)

Near the shores of lakes or rivers may be found many species of plants growing emersed or submersed. These grow at various depths, mostly rooted in the muddy or sandy bottom. The vegetation forms rather open patches in some places, and a continuous, tangled, aquatic garden in others. Especially in late summer, the growth of some of these communities is very dense. In these places, however, we find, partly intermixed, two kinds of Formations, the one Semi-cold emersed Formation comprising the so-called floating species and the other Semi-cold submersed Formation.

(1) **Semi-cold emersed Formation.** — Plants of this group are adapted to life partly in water and partly in air. They usually have extensive underground or creeping stems which are rooted in the mud and spread rapidly. The roots exhibit the usual characters of plants growing in water-logged soil. The leaves of amphibious plants show the greatest variation in both form and structure when the plant is subjected alternately to air and water environment. When they develop under water, they take the form and structure of submerged leaves. The aerial leaves are usually large and entire, showing a marked tendency to increase their exposed surface.

(i) ***Pharagmites longivalvis*—Association.** This occurs in the southern Manchurian Plain and North China Regions.

a) *Phragmites longivalvis*—Sociation.

b) *Phragmites longivalvis—Zinzania latifolia*—Sociation.

c) *Zinzania latifolia—Sparganium stoloniferum*—Sociation.

(ii) ***Phragmites communis*—Association.** This occurs in the Davuria, Manchurian Plain, East Manchuria, and Mongolia Regions.

(iii) ***Typha angustata—T. Davidiana*—Association.** This occurs in the Mongolia, North China, Manchurian Plain, East Manchuria Regions (cf Fig. 70).

a) *Typha Davidiana*—Sociation.

b) *Typha angustata—Menyanthes trifoliata*—Sociation.

c) *Typha angustata—Iris ensata*—Sociation.

(iv) ***Nelumbo nucifera—Nuphar pumilum—Nymphaea tetragona*—Association.** This occurs in the North China, Manchurian Plain, and southern Davuria Regions.

a) *Nelumbo nucifera—Nymphaea tetragona*—Sociation.

b) *Nuphar pumilum—Nymphaea tetragona—Nymphoides peltatum*—Sociation.

c) *Scirpus Tabernaemontani—Alisma orientale*—Sociation.

d) *Trapa bispinosa—T. Maximowiczii—Monochoria Korsakowii*—Sociation.

e) *Persicaria amphibia*—Sociation.

f) *Potamogeton Tepperi—P. natans*—Sociation.

(2) **Semi-cold submersed Formation.**—The leaves of these plants are greatly reduced in size and thickness, having a finely dissected, linear, or ribbonlike form. In proportion to the tissue involved in the reception of the diffused light, the thin leaves present an increased surface. Since most of them are restricted to shallow waters and to the vicinity of shores, they mostly grow as a rule intermingled, but the following Associations are recognized in relation to their water nature.

(i) ***Ranunculus flaccidus—Potamogeton pusillus*—Association.** This occurs in the hard water rich in lime showing somewhat alkaline reaction (cf Fig. 71).

(ii) ***Najas marina—Potamogeton crispus*—Association.** This occurs in the hard water showing considerable alkaline reaction, sometimes comprising some species of *Chara* and *Nitella.*

(iii) ***Myriophyllum spicatum—Ceratophyllum demersum—Utricularia vulgaris*—Association.** This occurs in the fresh-water.

(D) Temperate Forest Formation-group (Panformation)

(Temperate (moist) summer-green Forest and Temperate semi-dry needle-leaved Forest Formations)

This Formation-group is one of the most extensive forest communities and but for arid areas, generally occurs throughout the ranges of mountainous or hilly parts where the altitude or latitude does not permit the development of Boreal or Subalpine Forest Formation-group. Its widest contact, especially in the north, is with the latter Formation-group; and the two are always recognized touching each other or mingled together, but these two Formation-groups differ considerable in composition, origin, and climatic and successional relations. The vertical range of this Formation-group often exceeds 2000 meters in the North China Region and probably somewhat less in the East Manchuria Region. Along the lower margin, this makes the most varied contact with Prairie Formation or Temperate tall Herbage Wood Formation.

(1) **Temperate** (moist) **summer-green Forest Formation.**—This is unique in being the only Forest Formation of the broad-leaved deciduous life form in Northern East-Asia. It is essentially a temperate forest in contact

Fig. 70. *Typha angustata—T. Davidiana*—Association in the Mongolia Region (face P. 601). (M. TAKAHASI)

Fig. 71. *Ranunculus flaccidus* PERS. in a somewhat hard water pond in the southern Mongolia Region (face P. 602). (M. TAKAHASI)

Fig. 72. *Salix rorida—S. viminalis*—Association in the Davuria Region (face P. 605). (M. TAKAHASI)

Fig. 73. *Salix koreensis*—Sociation is persisting along streams in Prairie Formation (face P. 605). (M. TAKAHASI)

with the coniferous forests of Boreal or Subalpine Forest Formation-group, on the one hand, and Warm-temperate (moist) ever-green Forest Formation, on the other. Together with Prairie and Steppe Formations, it forms the great climatic vegetational mass of the continent.

A climate marked by a moderately warm, long, fairly humid summer, which is favourable to trees with deciduous leaves, and by winters during which the surface soil is frozen and the absorption retarded, is characteristic of this Formation. Owing to the altitude and the relationships with ground-water in the habitat, this Formation may well be subdivided into the two Subformations, Fringing and Terrace summer-green Forest and Montane summer-green Forest Subformations.

(a) **Fringing and Terrace summer-green Forest Subformation.** In this Subformation the following Associations are observed:

(i) ***Salix rorida—S. viminalis*—Association** (in the Davuria Region) (cf Fig. 72).

(ii) ***Salix Matsudana*—Association** (in the North China Region).

(iii) ***Salix koreensis*—Association** (in the East Manchuria Region) (cf Fig. 73).

(iv) ***Populus Simonii*—Association** (often comprising *P. Maximowiczii*).

(v) ***Ulmus pumila*—Association.**

Long tongues of *Salix rorida—S. viminalis*—, *Salix Matsudana*—, or *Salix koreensis*—Association persist along the streams in Prairie Formation, while island-shaped masses of *Populus Simonii*— or *Ulmus pumila*—Association occur on the isolated terraces in Prairie Formation and in ravines or on sand hills in Steppe Formation.

Populus Simonii— and *Ulmus pumila*—Associations have so broadly stretches as to distribute from the Davuria Region through the Manchurian Plain Region to the North China and Mongolia Regions.

Besides these Associations, especially in the plain of the North China Region, the cultivation of farm crops, the reckless cutting of trees, the repeated burning by fires, etc. during more than four thousand years and dense population, must have eradicated the wild forms of vegetations there, which otherwise should have still existed. Even in such places as the properties of the temples, which are generally under special care, taking away many trees by selective cuttings or the invasion of predominant thorny shrubs, such as *Zizyphus jujupa* MILL., *Caragana microphylla* LAM. etc.,(1) have deteriorate the primary forms of the plant communities. This retrogressive condition of the

(1) Sometimes *Gleditsia heterophylla* BUNGE or *Hippophae rhamnoides* L.

plant succession may bring about a change of local climate or bad soil conditions in the region, consequently the more delicate species might die off from the region. Under these circumstances, it is inevitable to enumerate simply the native trees which have been witnessed by the writer during his field investigations as follows:

Ulmus macrocarpa HANCE,	*U. laciniata* MAYR.,
U. propinqua var. *suberosa* MIYABE,	*U. Davidiana* PLANCH.,
U. parvifolia JACQ.,	*Ailanthus altissima* SWIN.,
Sophora japonica L.,	*Populus Simonii* CARR.,
P. alba L.,	*P. tomentosa* CARR.,
P. cathayana REHD.,	*P. laurifolia* LEDEB.,
Juglans regia L.,	*Gleditsia horrida* MAK.,
G. sinensis LAM.,	*G. heterophylla* BUNGE,
Albizzia julibrissin DURAZZ.,	*Robinia pseudoacacia* L. (not native),
Catalpa ovata DON.,	*C. bungei* C. A. MEY.,
Koelreuteria paniculata LAXM.,	*Xanthoceras sorbifolia* BUNGE,
Broussonetia papyrifera VENT.,	*Fraxinus Bungeana* DC.,
Pterocarya rhoifolia SIEB. & ZUCC.,	*Cedrela sinensis* JUSS.,
Tamarix juniperina BUNGE,	*Salix caprea* L., etc.

(b) **Montane summer-green Forest Subformation.** This Subformation varies in composition with the factors of the habitats, especially climatic factors based on latitude, altitude, and distance from the sea, hence comprises different Associations whose distribution ranges, especially in the case of the leading ones, as may be seen in the map of ecological regions (cf Fig. 49).

Many Associations of the East Manchuria Region are wanting in the Davuria or North China Region, and conversely, the more important Associations in the latter two Regions are lacking in the former. But some Associations, such as *Quercus mongolica*—Association, extend all over these three regions, although in the North China Region it is less frequent than in the other two.

In this Subformation the following Associations and Sociations are observed:(1)

(i) ***Betula platyphylla*** (subsp. *mandshurica*)—***Populus Davidiana*—Association.**

1) *Betula platyphylla* (subsp. *mandshurica*)—Consociation (Subassociation). This occurs in the northern parts of the East Manchuria Region, where it usually prevails on terraces in large valleys between rolling mountains. It is confined, both as regards soil moisture and atmospheric humidity, to the

(1) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 1509–1512, 1657–1662.

comparatively cooler and wetter parts, under which circumstances, latitude 45° forms a fairly definite boundary on the hilly lands (300-500 m high), whereas at a higher altitude the boundary occurs at about 41°, for the temperature increase in altitude can be compensated by a decrease in latitude, the rainfall being about the same.

In height, the first storey averages about 15 m. The second storey is usually composed of *Acer ukurunduense* TRAUTV. and *A. tegmentosum* MAX. Young trees of dominants are of course also present. Lianes and creepers usually occur, but are not so abundant.

The seral stages from bare land to this community is usually found on the south—west slopes where burned areas are most prevalent. It also occupies such new sites as that found after felling or wind throwing. At any rate, as already referred under "Light intensity and total duration", these rapid occupations of bare land areas depend mainly upon its light demanding nature and also upon its small light seeds which are well adapted for wind transportation.

This Consociation may well be subdivided into the following Sociations:

a) *Betula platyphylla* (subsp. *mandshurica*)—Sociation.

b) *Betula platyphylla* (subsp. *mandshurica*)—*Populus Davidiana*—Sociation.

c) *Betula platyphylla* (subsp. *mandshurica*)—*Larix olgensis*—Sociation.

2) *Populus Davidiana*—Consociation (Subassociation). This is usually found along the slopes near streams or ponds and on the tops of tablelands where the drainage is good; it appears to be confined to relatively dry soils of wetter sites. In the former case, we occasionally meet with some *Larix*, *Picea* or *Phellodendron*, and in the latter *Quercus* or *Acer*. The average height of the dominant storey is about 13 m.

(ii) ***Betula platyphylla—Populus Davidiana*—Association.** This occurs in the Davuria Region, and disregarding the mere variations in the subsp. of the *Betula*, the dominants are the same in the above Association, and except for the cooler condition of the site, the other habitat conditions have the similar nature to that of above mentioned Association.

The undergrowth usually consists of *Corylus mandshurica* MAX. and *Rhododendron dauricum* L. As a rule none of the lianes and creepers can be found.

1) *Betula platyphylla*—Consociation (Subassociation).

a) *Betula platyphylla—Populus Davidiana*—Sociation.

b) *Betula platyphylla*—Sociation.

c) *Betula platyphylla—Larix Gmelini*—Sociation (cf Fig. 74).

(iii) ***Quercus mongolica*—Association.** This is widely distributed over the East Manchuria, Davuria, and North China Regions, as has already been mentioned. It mostly occupies the neighbourhood of the lower mergin of Montane summer-green Forest Formation or the regions alongside it, its altitudinal range being from sea level to about 700 m. It is usually found on sunny slopes with a south—west aspect. Although it is true that this *Quercus* penetrates also far to the north, or higher into Cold-temperate needle-leaved Forest Formation than other species of the same genus, but it does not undergo complete "podsolisation" in these places, seeing that it requires greater warmth than in the latter Formation. Thus, even in this case, the soil is usually thin with coarse rock particles on dry areas of granite, or on fresh sites after landslides. It is subdivided into the three Consociations, *Quercus mongolica*—, *Quercus mongolica—Betula davurica*—, and *Betula davurica*—Consociations.

1) *Quercus mongolica*—Consociation (Subassociation). This occurs in the East Manchuria Region and partly in the Manchurian Plain or North China Region. Owing to its habit as a pioneer, seedlings of *Quercus* usually make a pure community on bare areas, such as found after landslides, burnings, or heavy felling, or wind throwing, as also various construction worked, such as railroads, roads, or dykes. As the Liaotung (遼東) Peninsular is reached, this Consociation (comprising *Q. mongolica* var. *liaotungensis* NAKAI and *Q. McCormickii* CARR.) gradually loses its typical structure, that is, the constitution is modified and *Pinus tabulaeformis* is freely mixed with it, eventually resulting in another Association of which further later. The main dominant is always *Quercus*, with *Acer mono, Populus Davidiana, Fraxinus rhynchophylla*, and *Betula Schmidtii* as the commonest codominants, making up the respective Sociations. Besides these codominants, there are occasionally *Fraxinus mandshurica* RUPR. and *Phellodendron amurense* RUPR. The undergrowth generally consists of *Lespedeza bicolor* TURCZ. and *Rhododendron dauricum* L. The lianes and creepers are usually only *Vitis amurensis* RUPR., and not at all abundant.

This Consociation may well be subdivided into the following Sociations:

a) *Quercus mongolica*—Sociation.

b) *Quercus mongolica—Acer mono*—Sociation.

c) *Quercus mongolica—Populus Davidiana*—Sociation.

d) *Quercus mongolica—Fraxinus rhynchophylla*—Sociation.

e) *Quercus mongolica—Betula Schmidtii*—Sociation.

2) *Quercus mongolica—Betula davurica*—Consociation (Subassociation). This occurs in the southern parts of the Davuria and the northern part of the East Manchuria Regions, being usually found on sunny terraces or on low hills where drainage is good. Especially in the former region, it so happens that since *Quercus* unfold its leaves very late, the lower storeys of the forest are well illuminated up to late in the spring, although the period is so short, that there is abundant development of early flowering herbs, whereas in the midsummer, on the contrary, there are few flowers and the herbaceous layer has the character of shade vegetation.

This Consociation may well be subdivided into the following Sociations:

a) *Quercus mongolica—Butula davurica*—Sociation.

b) *Quercus mongolica—Betula costata*—Sociation.

3) *Betula davurica*—Consociation (Subassociation). This occurs mostly in the Davuria Region and partly in the northern part of the East Manchuria Region, and on several mountains in the North China Region. It appears to be confined to rather wetter sites in the former two regions, but it occurs also on relatively dry soils in the latter region. In the former case it is occasionally accompanied by *Salix Caprea* L., resulting in a specific Sociation.

This Consociation may well be subdivided into the following Sociations:

a) *Betula davurica*—Sociation.

b) *Betula davurica—Salix Caprea*—Sociation.

(iv) ***Ulmus propinqua*—Association.** This occurs mostly in the East Manchuria Region, where it grows as a rule along river valleys or ravines. It appears to be confined to relatively moister soils. Everywhere the undergrowth or shrub layer is usually fairly dense, with the lianes and creepers so thickly developed that man can hardly pass through it.

1) *Ulmus propinqua*—Consociation (Subassociation).

a) *Ulmus propinqua*—Sociation.

b) *Ulmus propinqua—Pinus koraiensis*—Sociation.

c) *Ulmus propinqua—Populus koreana—Chosenia macrolepis*—Sociation.

d) *Ulmus propinqua—Tilia mandshurica*—Sociation.

e) *Ulmus propinqua—Juglans mandshurica—Tilia amurensis*—Sociation.

In the North China Region the Subformation seems to have now split into fragments and deteriolated considerably owing to an extensive destruction of

the forests mainly by man, directly or indirectly. It is, therefor, very difficult to comprehend the vegetations belonging to this Subformation based on each unit of the Association—system. But at least the following Associations may be recognized:

(v) ***Tilia mongolica—Betula platyphylla*** (subsp. *mandshurica*)—**Association.**

(vi) ***Tilia mongolica—Quercus acutissima*** (var. *septentrionalis*)—**Association** (occasionally comprising *Q. veriabilis* BL.).

(vii) ***Quercus acutiserrata—Fraxinus rhynchophylla*—Association.**

(viii) ***Quercus dentata*—Association.**

(ix) ***Pterocarya stenoptera—Juglans mandshurica*—Association.**

Besides these Associations the following trees are also found to be growing scattered on the hilly mountains or at the foot of those mountains as small clumps or isolated trees, however the scarcity of natural origin in its strict sense, except in the places beyond easy access.

Quercus serrata THUNB., *Q. dentata* THUNB.,
Q. aliena BL., *Castanea mollissima* BL.,
C. sequinii DODE., *Celtis koraiensis* NAKAI,
C. Bungeana BLUME, *Aesculus chinensis* BUNGE,
Hovenia dulcis THUNB., *Rhus semialata* MURR.,
Styrax japonica SIEB. & ZUCC., *Acer truncatum* BUNGE,
A. davidi FRANCH., *A. Ginnala* MAX.,
Tilia mandshurica RUPR. et MAX., *Carpinus Turczaninovii* HANCE,
C. erosa BLUME, *Kalopanax pictum* NAKAI,
Betula albo-sinensis BURK., etc.

(2) **Temperate semi-dry needle-leaved Forest Formation.**—This Formation grows under a rainfall of 1800 mm in the coast ranges of the northern Koréa, which amount, however, decreases rapidly toward the west until in the North China Mountains it reaches 400 to 500 mm.

This Formation occurs over an altitudinal range from sea level to about 700 m (exceptionally more than 1500 m, such as on Mts. Wutai-Shan), usually forming a pure community on well drained sites with thin soils, especially on granite or gneiss areas and sandy soils. In this Formation the following Associations are observed:

(i) ***Pinus sylvestris*—Associaiton** (cf Fig. 75).

(ii) ***Pinus densiflora*—Association.**

(iii) ***Pinus tabulaeformis*—Association.**

(iv) ***Pinus Tokunagai*—Association.**

(v) ***Pinus bungeana*—Association.**

Three kinds of great masses of these Associations, i. e. *Pinus sylvestris*—, *P. densiflora*—, and *P. tabulaeformis*—Associations, are distributed over a very wide range being seldom mixed together.

Pinus sylvestris—Association, comprising *Pinus Takahasii* NAKAI, is of wide range, both in altitude and in geographical area, but in the regions under consideration it is restricted to the far northwestern parts, except, however, on the north side of Lake Hingkaihu (興凱湖). In the northern Mongolia Region, this Association pushes far to the south into Steppe Formation where it occurs in restricted habitats of special character, such as sand dunes or sandy terraces(1) which is also exposed to strong winds, where at first it had the character of dunes, but were finally occupied by *Pinus* species and so remains. Magnificent examples of such sandy forest areas are to be found in the neighbourhood of the town of Hailar (海拉爾) and near Hantzelei. The soil cover often simply consists of a few pine needle, twigs, and cones, with a few herbaceous vegetations, and some *Pinus* seedlings.

Pinus densiflora—Association is also distributed so widely as to be found in Korea and in the whole of Japan proper, but in the regions under consideration it is limited also to a small area in the southern East Manchuria Region. Consequently, *P. tabulaeformis*—Association ranks as the major Formation in the present regions. As already mentioned, it usually forms a pure community, but in the Liaotung Peninsular, there is a peculiar mixed community, a kind of Sociation, with an upper storey of *P. tabulaeformis* and a lower one of *Quercus mongolica*. Although several other species of *Pinus*, such as *P. Tokunagai* NAKAI and *P. bungeana* ZUCC., are of local importance in the North China Region, they are all of very restricted distribution.

Owing to its more dry habitat, the shrubby layers of this Formation are not so well developed, and few species have the same characteristics as in Temperate moist summer-green Forest Formation.(2)

(vi) ***Juniperus rigida*—Association.** Besides in the East Manchuria, Davuria and North China Regions, this occurs occasionally in the southern parts of the Mongolia Region, but no communities in large scales can be found. This shows a great tolerance for rather rigorous havitats, but has compara-

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(1) It is said that *P. sylvestris* grows also on peat in the northern parts of European Russia and Finland.

(2) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 66–67.

tively light demanding nature. It can grow well on poor soils where the great many other trees can hardly stand.

(vii) ***Biota orientalis*—Association.** This occurs in the North China and southern parts of the Mongolia Regions. But at present there found few natural communities, except in Jehol (熱河) or Shansi Province where comparatively sparse thickets of natural kind are found on the rocky sunny slopes of lower altitudes in several places. The Chinese used to plant this tree in the precincts of temples or grave-yards for making coffins by its timbers and incense-sticks from the roots.

(E) **Boreal or Subalpine Forest Formation-group** (Panformation).[1,2,3,4,5,6]

As the name suggests, the subalpine forest occupies the upper slopes of the high ranges in temperate regions, usually forming a belt 600 to 900 m wide between Alpine Vegetation Formation-group above and Montane summer-green Forest Subformation below. The boreal forest, which is essentially the same as the subalpine forest, lies in contact with Tundra Formation along its entire northern border, but nowhere reaching the polar sea. But along the rivers, the forest, having a reduced form, may extend farther into the Formation. This is attributed to the better drainage of the valley slopes and at least to the fluidity of the ground water there, so that ice is not formed so close to the soil surface. Besides, the valley slopes are better protected from wind, while the flowing water contains much oxygen, so beneficial to the respiration of plant roots.

Since, in the Yablonoi and Stanovoi Mountains, the boreal forest mixes with the subalpine forest, these two groups of forests make up the present Boreal or Subalpine Forest Formation-group, with the result that the geographic and topographic relations of the Formation-group serve to explain the subalpine or boreal climate in which it flourishes. This climate is characterized by a short growing season, relatively high precipitation, and wide diurnal and seasonal ranges of temperature. Even at the lower limit, the

(1) KITAGAWA, M.: Lineamenta Florae Manshuricae. Rep. Inst. Res. Manch., **3**, Append. 1 (1939).
(2) LEE, S. C.: Forest botany of China. (1935).
(3) CHEN, Y.: Illustrated manual of Chinese trees and shrubs (Chinese). (1937).
(4) CHOW, H.: Illustrated manual of trees in Hopei (Chinese). (1934).
(5) HU, H. H. & W. H. CHUN,: Icones Plantarum Sinicarum. (1930–1937).
(6) TAKENOUCHI, M.: A preliminary report on the conifers indigeous in Manchoukuo, with special reference to their taxonomy and their distribution (Japanese). Rev. For. Exper., Manch., **3** (1931) 243–298.

Fig. 74. *Betula platyphylla—Larix Gmelini*—Sociation on Mts. Great Khingan (大興安嶺) (face P. 608).
(M. TAKAHASI)

Fig. 75. *Pinus sylvestris*—Association on the riverside cliff of R. Amur (face P. 610). (M. TAKAHASI)

Fig. 76. A bird's-eye view of *Picea jesoensis—Abies nephrolepis*—Sociation in the East Manchuria Region (face P. 616).
(permitted by authorities)

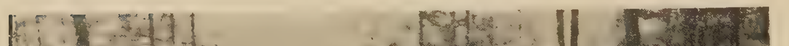

Fig. 77. *Larix olgensis*—Sociation in the pumice areas on Mt. Hakutosan (face P. 622). (M. TAKAHASI)

growing season is nearly 4 months long, and at the upper, between 2 and 3 months. The mean temperatures are 3 to 10°C less than in Montane summer-green Forest Subformation, while near the timber line, frost occurs frequently during the summer. Although the precipitation is from 600 to 1800 mm a year in the greater parts of the areas, the total snowfall is not excessive and the air is relatively dry except for the eastern parts of the regions under consideration. In the northern parts, the ground is either covered with snow or it is frozen for nearly eight months in the year, the subsoil 1.5 to 2 meters below the surface being permanently frozen. In general, the drainage is poor and the soils are shallow and immature. In areas far to the north or of higher altitude near the timber line, the trees are much reduced both in stature and diameter considering their ages. This Formation-group comprises the two Formations, Cold-temperate needle-leaved Forest and Cold-temperate summer-green dwarf Forest Formations.

(1) **Cold-temperate needle-leaved Forest Formation.**—This formation occupies the greater part of the present Formation-group, its climax dominants being chiefly evergreen conifers, except, however, a few summer-green species. Owing to the seasonal aspect, this Formation may be subdivided into the two Subformations, Evergreen needle-leaved Forest and Summer-green needle-leaved Forest Subformations.

(a) **Evergreen needle-leaved Forest Subformation.** This Subformation is not uniform throughout its vast extent of area, the variation being due to mainly to the geographic distributional ranges of the many dominants, owing to which the composition of each community is changing from northern to southern. The most important Associations composing this Subformation are *Picea jesoensis—Abies nephrolepis—Pinus koraiensis*—Association in the East Manchuria Region, *Picea obovata*—Association in the Davuria Region, *Picea Mastersii*—Association in the North China Region.

(i) ***Picea jesoensis—Abies nephrolepis—Pinus koraiensis*—Association**[1] This Association, the largest and widely distributed in the East Manchuria Region which the writer delimited by basing on its distributional range, comprises the four Consociations, *Picea jesoensis—Abies nephrolepis*—, *Picea jesoensis—Pinus koraiensis*—, *Pinus koraiensis*—, and *Abies nephrolepis*—Consociations.

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(1) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 63–79, 1129–1136, 1296–1306, 1503–1512, 1657–1665.

1) *Picea jesoensis—Abies nephrolepis*—Consociation (Subassociation). This is usually found on the highest position of all Consociations mentioned above. It is subdivided into the following four Sociations:

a) *Picea jesoensis—Abies nephrolepis*—Sociation (cf Fig. 76). This Sociation usually occupies the highest position of the Consociation and grows at more than 900 or 1000 m in altitude. But on steep slopes of the northern site it occasionally descends down to 800 or 750 m. The canopy is fairly dense and makes the shade constantly, but at high altitudes on or near the tops of ridges it is sometimes found rather open and the trees stunted. There are generally five well-marked storeys or layers which may be referred to as the top storey (the dominant storey), the second storey (subdominant storey), the third storey, the undergrowth (the fourth storey), and the ground flora (the fifth storey). The typically well-developed community, in which the height of taller trees of the dominant storey varies in average from 17 to 22 m, is composed of *P. jesoensis* and *A. nephrolepis* which are from 160 to about 200 years old. It comprises *Betula costata* TRAUTV. as the commonest subdominant but sometimes with or without of which, *B. Ermanii* CHAM. (at high altitudes) or *B. platyphylla* (subsp. *mandshurica*) (at lower altitudes) or both. However, there are rarely *B. costata* or *Taxus cuspidata* SIEB. & ZUCC. being isolated from this Sociation as a pure community on the top of ridges or tablelands as the writer observed from an aeroplane. The second storey is usually composed of *Betula* (as cited above), *Tilia amurensis* RUPR., *Acer mono* MAX., *A. Tschonoskii* var. *rubripes* KOM., and *A. mandshuricum* MAX. In the third storey young trees of the dominants and subdominants are present. The most characteristic feature is the absence of lianes and creepers. The undergrowth or shrub layer in general is fairly thick; besides the seedlings of *A. nephrolepis* there are *Corylus mandshurica* MAX. & RUPR., *Ledum palustre* var. *angustum* N. BUSCH, *Rhododendron mucronulatum* TURCZ., *R. dauricum* L., and *Vaccinium Vitis-Idaea* L. The ground flora varies considerably, not so well developed, and shows the species such as *Oxalis acetosella* L., *Goodyera repens* R. BROWN, *Maianthemum bifolium* F. W. SCHMIDT, *Pyrola japonica* SIEB., *Clintonia udensis* TRAUTV. & MEY., *Linnaea borealis* f. *arctica* WITTR., *Equisetum hyemale* L., *Dryopteris crassirhizoma* NAKAI, and *Circaea quadrisulcata* FRANCH. & SAVAT. On Mt. Hakutosan a thick carpet of *Lycopodium clavatum* L., *L. serratum* THUMB., *L. complanatum* var. *dilatatum* NAKAI et HARA, etc. is occasionally found. Should this Sociation be destroyed by felling, fire, wind-throwing, etc., it would be repopulated first by *Betula* species.

b) *Picea jesoensis—Abies nephrolepis—Pinus koraiensis*—Sociation. This Sociation is found usually below the preceding one and occupies the middle portion of the mountains. It generally developes fairly good ranging from 700 to 1000 m in altitude. The soil is almost loamy and of diorite origin, and somewhat moister and cooler. On the slopes of northern site it occasionally descends to about 600 m, but on the sandy soil of granite or gneiss origin in the northern part, it ascends to 850 m or more. These differences of soils not only have the influence on the range of Sociations, but also on the mixed percentage of their constituent trees. As its constituents *P. jesoensis* takes generally 40% or more of the top and second storeys, at least when *A. nephrolepis* and *Picea koraiensis* are included, at any rate, it attains the majority of the constituents. *Pinus koraiensis* does not account more than 20%. There are usually four or five well-marked storeys as follows:

Top storey:	open canopy of *P. jesoensis* and *Pinus koraiensis*, 25–32 m, 200–280 years old.
Second storey:	*A. nephrolepis*, 20–24 m, sometimes mixed with *Picea koraiensis*, *Fraxinus mandshurica* RUPR. and *Tilia amurensis* RUPR.
Third storey:	*P. jesoensis*, *A. nephrolepis*, *Acer* sps., and *Syringa amurensis* RUPR., 10–14 m, 50–100 years old. In more open places there are *Acer tegmentosum* MAX. and *Tilia mandshurica* RUPR.
Fourth storey: (undergrowth)	*Corylus mandshurica* MAX., *Rosa davurica* PALL., *Eleuther coccus* MAX., *Schizandra chinensis* BAIL., *Viburnum Sargenti* KOEH., *Ribes Maximowiczianum* KOM., etc.
Fifth storey: (ground flora)	*Lycopodium clavatum* L., *L. serratum* THUNB., *Maianthemum bifolium* F. W. SCHMIDT, *Oxalis acetosella* L., etc.

Lianes and creepers consist mainly of *Vitis amurensis* RUPR.

Should this Sociation be destroyed, it would be first recovered by *Betula platyphylla* subsp. *mandshurica* KITAG.

c) *Picea jesoensis—Abies nephrolepis—Larix olgensis*—Sociation. This Sociation is generally of comparatively small scale, lying near and arround the swampy ravines in mountainous regions, and the mixed percentage of *Larix* is always increasing proportionally to the soil moisture. But on Mt. Hakutosan the circumstances are completely altered, owing to its undeveloped soils of volcanic origin. The Sociation is rather prevalent irrespective of the soil moisture (characteristic features of *Larix* species will be referred to in details later). At any rate, the constituents of the Sociation are almost same as the preceding one, except *Pinus* replaced by *Larix*.

d) *Picea jesoensis—Abies nephrolepis—Picea koraiensis*—Sociation. This

Sociation is recognized on the low mountains in the northern parts of the East Manchuria Region or in comparatively high altitude where no *Pinus koraiensis* is found. Under these circumstances it may be thought that in the b)—Sociation *Pinus* is replaced by *Picea koraiensis.* But on Mt. Hakutosan, besides the species cited above, *Larix olgensis* sometimes takes place in this community to a certain extent.

2) *Picea jesoensis—Pinus koraiensis*—Consociation (Subassociation). This Consociation is usually found on the upland of comparatively lower altitude, especially near the swampy valleys. It is subdivided into the following two Sociations:

a) *Picea jesoensis—Pinus koraiensis*—Sociation. This Sociation occurs usually at sandy soils of granite or gneiss origin extending over from 700 to 850 in altitude, or in the valley terraces of the similar altitude. Occasionally it descends further downward in the case of loamy wetter soils on the slopes of northern site. There are usually four storeys as follows:

Top storey: *Picea jesoensis* and *Pinus koraiensis*, 25–35 m, 250–300 years old.

Second storey: *P. jesoensis*, 15–20 m, sometimes mixed with one or more species out of *Abies nephrolepis, Picea koraiensis, Larix olgensis, Tilia amurensis, Fraxinus mandshurica, Ulmus laciniata* MAYR., but rarely with *Juglans mandshurica* MAX.

The undergrowth and ground flora are also prevalent and consist of almost the same species as that of 1) b)—Sociation.

Lianes and creepers are comparatively well developed, consisting mainly of *Vitis amurensis* and *Actinidia arguta* PLANCH. et MIQ.

b) *Picea jesoensis—Pinus koraiensis—Abies holophylla*—Sociation. This Sociation is rarely found in the ravines or depressions of loamy soils in the mountains in the southern part of the East Manchuria Region. Thus in regard to the soil moisture and to the atmospheric humidity, the Sociation is confined to the moister site. Besides *P. jesoensis* and *P. koraiensis*, sometimes *A. holophylla* MAX. stands as a constituent, but mostly as a subordinate member.

3) *Pinus koraiensis*—Consociation (Subassociation). This is usually found on the lowest position of the Consociations as mentioned above. It is subdivided into the following two Sociations:

a) *Pinus koraiensis*—Sociation. This is found on the lower part (about 300–650 m) of mountains having moderately moist and fairly rich sandy soil. *P. koraiensis* forms a constituent of considerable amount, sometimes amounting to 80 per cent, while other trees such as *Picea jesoensis* and *Abies nephrolepis*

are either absent or occur rarely as isolated individuals. There are usually four or five well-marked storeys as follows:

Top storey: *Pinus koraiensis*, 28–35 m, 220–300 years old.

Second storey: Besides the *Pinus*, 20–25 m, 40–150 years old, there grow also one or more species out of *Tilia amurensis*, *Ulmus laciniata*, *Fraxinus mandshurica*, *Betula platyphylla* subsp. *mandshurica*, *B. costata*, *Acer mono*, *A. tegmentosum*, *Phellodendron amurense*, *Quercus mongolica*, *Juglans mandshurica*, etc.

Third storey: Besides several species of *Acer* (about 13 m), *Syringa amurensis* RUPR., *Maackia amurensis* RUPR. & MAX., *Aralia elata* SEEM., etc.

Fourth storey: *Corylus mandshurica* MAX., *Syringa velutina* KOM., *Philadelphus tenuifolius* RUPR. & MAX., *P. Schrenkii* RUPR., *Lonicera Maackii* MAX., *L. chrysantha* var. *crassipes* NAKAI, *Eleuther coccus* MAX., etc.

Fifth storey: *Cacalia hastata* subsp. *orientalis* KITAM., *Urtica angustifolia* FISCH. et HORN., *Brachybotrys paridiformis* MAX., *Oxalis acetosella* L., etc. (in moister site): *Equisetum hyemale* L., *Dryopteris crassirhizoma* NAKAI, *Athyrium pycnosorum* CHRIST, *A. brevifrons* NAKAI, *Thelypteris palustris* SCHOTT, etc.

As lianes and creepers—*Vitis amurensis* RUPR. and *Actinidia arguta* PLANCH. et MIQ. are found.

This Sociation is recognized as a comparatively stable community under natural conditions, but in late years it is apt to be destroyed by over-felling or forest-fire because of access to its location and, the reforestation of this damaged community is far more difficult than that of others.

b) *Pinus koraiensis*—*Picea jesoensis*—Sociation. This Sociation is dominated by *P. koraiensis* like the preceding one, but it has a considerable admixture of *P. jesoensis*, which sometimes amounts as much as to 30%. In loamy moister sites, this Sociation usaully occurs further downwards. The undergrowth is rich and various, containing many representatives of Summer-green broad-leaved Forest Formation. As lianes and creepers—*Vitis amurensis* and *Actinidia arguta* are of characteristic and well developed.

4) *Abies nephrolepis*—Consociation (Subassociation). This Consociation is usually found on the middle portion of subalpine zone, though not so extensively scaled, it is subdivided into the following three Sociations:

a) *Abies nephrolepis*—*Picea jesoensis*—*Vaccinium Vitis-Idaea*—Sociation. This Sociation usually occurs on the steep slopes of high altitudes or the rocky slopes of high latitudes, where the weather conditions are rather rigorous. It is characterised by the growth of the tree layer and ground flora well developed, but for dwarf shrubs, the shrub and herb layers are being of

subordinate importance. This consists mainly of *A. nephrolepis*, but sometimes of an admixture of *P. jesoensis*. The dwarf shrub layer is not closed and consists mainly of *Vaccinium Vitis-Idaea* and *V. uliginosum*, and occasionally comprises *Juniperus sibirica* BURGS., *Rhododendron chrysanthum*, *Linnaea borealis* f. *arctica* WITTR., etc. This Sociation is also characterised by a moss or lichen covering.

b) *Abies nephrolepis—Betula costata*—Sociation. This Sociation occurs on the moister sites of the upper half of wider ravines in the northeastern part of the East Manchuria Region. It is dominated by *A. nephrolepis*, but a considerable admixture of summer-green broad-leaved trees, such as *B. costata*, *Fraxinus mandshurica*, *Ulmus laciniata* and *Juglans mandshurica* is found in accompany. The thick woody undergrowth consists of shrubs such as *Prunus Padus* L., *Rhamnus argutus* MAX., *Rosa davurica* PALL., *Corylus mandshurica* MAX., and *Rhododendron davuricum* L. The herb layer is also rich and various, containing many representatives of the lower communities.

c) *Abies nephrolepis—Pinus koraiensis*—Sociation. This Sociation occurs on the comparatively gentle slopes of southern site. Besides *A. nephrolepis*, *P. koraiensis* may form a considerable part of its constituent, and occasionally *B. costata*, *Tilia amurensis*, *Acer ukurunduense* TRAUTV. & MEY. and *A. mono* MAX are also found. It may be considered that out of the 1)—b)—Sociation *P. jesoensis* is eliminated, but a phenomenon of such, in the nature of things, seems rather abnormal; therefore it is natural to be in a small scale.

(ii) ***Picea obovata*—Association.** This occurs in the Davuria Region, especially on Yablonovi Mountains, the north side of the river Shilka and the mountains westward from the river Lena in the East Siberia. It appears to be confined relatively to moister and darker soils rich in humus, and in the mountainous parts it stretches over the sites where are being protected from severe winds. The Association is dominated by *P. obovata—Larix Cajanderi*— and *P. obovata* –*Betula platyphylla*—Sociations. Owing to the difficulty of knowing the internal conditions of U. S. S. R., the explanations in details are not able to give here. However, here is only one example of this Association (not natural one in its true sense) lying fortunately within our access on the river vasin of Nun-Kiang (嫩江) 7 km south of Merhken (墨爾根). In this forest, the top storey (6–9 m) consists of *P. obovata* LEDEB. of 60–80 years old and a fairly dense shrubby undergrowth, and an understorey of small trees are found everywhere covering the ground up to a height of 2–4 m, but lianes and creepers are not prominent.

(iii) ***Picea Mastersii*—Association.** This occurs in the North China Region and its altitudinal range is from 1400 to 2200 m, comprising two Consociations, *P. Mastersii*—and *P. Mastersii—Larix Principis-Rupprechtii*—Consociations.

1) *Picea Mastersii*—Consociation (Subassociation). This Consociation is usually found on the lower half (1400–1800 m) of the Association cited above; it is subdivided into the following two Sociations:

a) *Picea Mastersii*—Sociation. This Sociation occurs at the moderately moist and rich soils, and the commonest subdominants are *Betula costata* and *B. davurica*, occasionally *B. platyphylla* (subsp. *mandshurica* KITAG.) and *B. chinensis*, especially in open sites.

b) *Picea Mastersii—P. Meyeri*—Sociation. The dominant of this Sociation is same as the preceding one, but it comprises *P. Meyeri* as the commonest codominant(1). It is found at comparatively lower altitudes and sometimes comprises *Pinus Tokunagai* NAKAI (as seen on Mt. Wuling-Shan) or *Betula platyphylla* (subsp. *mandshurica* KITAG.).

2) *Picea Mastersii—Larix Principis-Rupprechtii*—Consociation (Subassociation). This Consociation is situated at the moderately moist and comparatively rich soils, being prevalent on the portion ranging between 1700 and 2200 m in altitudes. Besides the dominant species, *P. Mastersii, Larix Principis-Rupprechtii* is found as a codominant, however the percentage of mixture changes according to the localities owing mainly to edaphic or biotic factors. Sometimes it comprises *B. platyphylla* (subsp. *mandshurica*) (on Mts. Wutai-Shan), and *B. davurica* (on Mts. Hsiao-wutai-Shan) as commonest subdominants at comparatively lower parts, and *B. chinensis*, *B. albo-sinensis* BURK. (comprising its var. *septentrionalis* SCHEID.) and *B. fruticosa* PALL. at upper parts.

(b) **Summer-green needle-leaved Forest Subformation.** This Subformation has a marked tendency to form a pure community near the timber line, however, somewhat of dwarf nature under the rigorous conditions, while in the lower altitudes it occurs usually at swampy depressions or alluvial cones. However, this Subformation is prevailing as a climax community irrespective of its zonal location on volcanic immature soils, for instance on the eastern or southeastern extensive slopes of Mt. Hakutosan (白頭山) or at

(1) "Codominant" refers to trees in the upper canopy whose frequency is less than that of the dominants. "Subdominant" refers to slightly smaller trees which are growing between rather underneath the dominants and codominants; their frequencies may be higher or lower than those of the latter.

anywhere out of the distribution ranges of every successful shade-bearing plants, e. g., in the greater parts of Great Khingan (大興安) Mountains. In the strict sense, its dominants are restricted to only one genus, *Larix* species; and these, *Larix olgensis*—, *L. Gmelini*—, and *L. Principis-Rupprechtii*—Associations are recognized in the regions under consideration.

(i) ***Larix olgensis*—Association.** This occurs in the East Manchuria Region and occupies the places rather unfavourable for the most of other trees, while *Picea jesoensis*—*A. nephrolepis*—*Pinus koraiensis*—Association is, as already referred, most widely distributed over the rich and podsolised soils in the same region. The ecological characteristics of these trees in these two Associations are noted as follows:[1, 2]

Larix (light-demanding) cannot exist or grow well under the shade of *Abies* or *Picea*.	*Abies* or *Picea* (shade-bearing) grows well under the shade of *Larix*, if edaphic conditions are favourable.
A relatively poor soil suffices for its growth.	It demands relatively rich and moist, but not boggy soil.
The species is quite independent of soil moisture.	The species is quite tolerant of light conditions.

Thus the latter overshadows and eliminates the former on rich and moist soils, while on swampy sites or alluvial cones the former can remain survived by struggling for light.

The former Association comprises the two Consociations, *L. olgensis*— and *L. olgensis*—*Betula platyphylla* (subsp. *mandshurica*)—Consociations.

1) *Larix olgensis*—Consociation (Subassociation). This is usually found on the volcanic immature soils or the place after a landslide occurred at comparatively higher altitudes, sometimes on the rocky places near the tree limit; it is subdivided into the following six Sociations:

a) *Larix olgensis*—Sociation (cf Fig. 77). This Sociation occupies extensive areas on the eastern or southeastern parts of the "Great Hakutosan Area", where is covered with the immature soil of mainly pumice origin, and sometimes of basalt. It occurs at from 1500 to 1800 m in altitude and makes almost a pure community, which is sometimes accompanied by the trees such as *Abies nephrolepis*, *Betula costata*, *Populus Davidiana* DODE, *Alnus mand-*

(1) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 1503–1504, 1662–1663.

(2) ——: Species of *Larix* distributed in East-Asia and their ecological characteristics (Japanese). Bot. and Zool., 9 (1941) 489–496.

shurica HAND., *Sorbus pohuashanensis* HEDL., etc. in the second storey. The undergrowth, which is usually not dense, consists of *Rosa davurica, Ribes Maximowiczianum* KOM., *Viburnum koreanum* NAKAI, *Lonicera caerulea* L., *Ledum palustre* var. *angustum* N. BUSCH, etc.

b) *Larix olgensis—Betula costata*—Sociation. The Sociation is recognized by a certain modified type in the limited areas within the upper portion of a)—Sociation. This is distinguished from the preceding by the subdominant of *Betula costata* which is well grown to the size of tall trees, and further upward it passes over to Cold-temperate summer-green dwarf Forest Formation (it will be referred in the next section).

c) *Larix olgensis—Populus Davidiana*—Sociation. This is usually found in the areas burned formerly in the lower portion of a)—Sociation, occupying a comparatively well-drained site of volcanic immature soils. Sometimes *Populus koreana* REHD. and *Tilia amurensis* are also found in the second storey. It is noticeable that fireweed (*Chamaenerion angustifolium* SCOP.) is often forming a large aggregated community in the open sunny site of this Sociation. The undergrowth is usually quite similar to that of a)—Sociation. The most characteristic herbs are *Chamaenerion* (cited above) and *Synurus deltoides* NAKAI, and sometimes *Cacalia hastata* subsp. *orientalis* KITAM., *Ligularia jaluensis* KOM., etc. are found.

d) *Larix olgensis—Vaccinium Vitis-Idaea*—Sociation. This Sociation thrives better as a pure community in cold and moist sites of high mountains, however, growing deformedly in height and diameter. On Mt. Hakutosan *Larix* is usually found to be a forest-tree of 20 m or more in height though being dwarfed as to 1 m or less near the timber line.

In the forest of this kind, the ground flora consists of a dense growth of *V. Vitis-Idaea, V. uliginosum* L., *Rhododendron chrysanthum* PALL., *Phyllodoce caerulea* BAB., etc., having a thick carpet of mosses and lichens everywhere. So this Sociation may be considered to be a kind of seral stage from Heath Formation to a)—Sociation or vice versa.

e) *Larix olgensis—Picea jesoensis—Abies nephrolepis*—Sociation. This Sociation is usually observed at the lower part from a)—or b)—Sociation growing at the soil of moderately moist and rather rich. Besides *L. olgensis*, the first storey generally consists of *P. jesoensis, A. nephrolepis*, and *Picea koraiensis*. Trees in the second storey are *Alnus mandshurica, Sorbus pohuashanensis, Acer unkurunduense, A. tegmentosum, A. Tschonoskii, B. costata*, etc.

The ground flora consists mostly of *Maianthemum bifolium, Clintonia udensis* TRAUTV. & MEYR., *Cacalia hastata* subsp. *orientalis* KITAM., etc.

f) *Larix olgensis—Pinus koraiensis*—Sociation. This Sociation is located at the lower part of mountain slopes. In the dominant storey of *L. olgensis* and *P. koraiensis, Picea jesoensis* or *Abies nephrolepis* are observed as supplementary members, but occassionally a few representatives of *Pinus densiflora* SIEB. & ZUCC. and *Betula platyphylla* (subsp. *mandshurica*) are also found.

Among the undergrowth the following shrubs are usually found:

Corylus mandshurica MAX., *Eleutherococcus senticosus* MAX., *Lonicera Maackii* MAX., *S. amurensis* RUPR., *Philadelphus Schrenkii* RUPR., *Maackia amurensis* RUPR., *Syringa velutina* KOM., *Rhamnus davuricus* PALL., etc.

The ground flora consists mostly of the species as noted below:

Cacalia hastata subsp. *orientalis* KITAM., *Aconitum Kusnezoffii* REICH., *Urtica angustifolia* FISCH. et HORN., *Thelypteris palustris* var. *pubescens* FERN., *A. pycnosorum* CHRIST, *Lingularia Fischeri* TURCZ., *A. albo-violaceum* KOM., *Equisetum hyemale* L., *Athyrium brevifrons* NAKAI et MORI, etc.

2) *Larix olgensis—Betula platyphylla* (subsp. *mandshurica*)—Consociation (Subassociation). This Consociation occupies swampy places of the depression, but occasionally occurs along the streams in wide ravines and sometimes on the mountain-foot of the northern parts. The dominant storey usually consists of *Larix olgensis*, 28–32 m high, and 250–300 years old. In the second storey, besides young trees of dominant species, *Betula platyphylla* (subsp. *mandshurica*) (10–14 m high, 90–150 years old) is found as the commonest subdominant, sometimes mixed with *Picea jesoensis* or *Pinus koraiensis.*

(ii) ***Larix Gmelini*—Association.** This Association occurs in the Davuria Region. From the edaphic point of view, its distribution areas may be divided into two zones—the one is northern podsol-swamp, where the peat moors are especially widespread, and the other is southern simple podsol. In the Great Kingan Mountains these two characteristic zones border on the upper basin of the Gan-Ho (根河) river. The Association comprises two Consociations, namely *Larix Gmelini*—and *L. Gmelini—Betula platyphylla*—Cosociations.

1) *Larix Gmelini*—Consociation (Subassociation). This Consociation grows under various edaphic conditions, except the places where *Salix* growing in spite of being threatened by periodic inundations every year, irrespective of the soil of swampy, dry, rich or poor as the shade-bearing species rarely occur

in the Davuria Region; it does not appear so noticeable as *Larix olgensis* – Association as already cited, which is confined mostly to special edaphic conditions in the East Manchuria Region. Under these circumstances a well developed Consociation occurs in the moderately moist and fairly rich soil such as on a gentle sunny slope near the streams in the southern simple podsol zone where grow the taller trees of 27–30 m in height, 0.75–1.5 m in diameter, and 200-250 years old. This Consociation can be subdivided into the following three Sociations:

a) *Larix Gmelini*—Sociation (cf Fig. 78). This Sociation consists mainly of *Larix*, but sometimes of isolated individuals of *Betula platyphylla, Tilia amurensis*, and *B. davurica*, and occasionally of *Picea obovata* (in the northern parts) or *Quercus mongolica* (in the southern parts). As usual the tree and moss layers are well developed, but the shrub and herb layers are of subordinate importance. The root system of these trees is particularly superficial, so wind-throwing trunks are frequently observed everywhere especially in the zone having permanently frozen layer. Seedling of *Larix* are fairly common along the forest-pathes or deforested areas, sometimes they grow so densely as to show a bush-like appearance. The herb and dwarf shrub layer is closed in the southern simple podsol zone and consists of the following species:

Spiraea media var. *monbetsusensis* CARDOT.,
Ribes pauciflorum TURCZ. et LEDEB.,
Rhododendron dauricum L.,
Fragaria corymbosa L. LOSINS.,
Viola acuminata LEDEB.,
Cacalia hastata L.,
Thalictrum aquilegifolium L.
Sorbus amurensis KOEHNE,
Cornus alba L.,
Calamagrostis Langsdorffii TRIN.,
Vaccinium Vitis-Idaea L.,
Maianthemum bifolium F. W. SCHMIDT,
Pyrola incarnata FISCH. et DC.,
Luzula rufescens var. *macrocarpa* BUCH.,
Athyrium brevifrons var. *angustifrons* KODAMA, etc.

In the northern podsol-swamp zone, the layer makes patches among continuous carpets of *Sphagnum*, and the following species are found:

Betula fruticosa PALL.,
Spiraea salicifolia L.,
Alnus sibirica FISCH. et TURCZ.,
Salix myrtilloides L.,
R. Diacantha PALL.,
Vaccinium Vitis-Idaea L.,
Linnaea borealis L.,
Rubus saxatilis L.,
Aquilegia parviflora LEDEB.,
Juniperus sibirica BURGS.,
Sorbus amurensis KOEHNE,
Rosa pimpinellifolia L.,
Ribes mandshuricum KOM.,
Lonicera caerulea var. *edulis* REGEL,
V. uliginosum L.,
Potentilla fruticosa L.,
Cypripedium guttatum SWARTZ,
Trientalis europaea L., etc.

b) *Larix Gmelini—Pinus sylvestris*—Sociation. This Sociation usually occurs in the northern part of the Davuria Region. The Sandy Loam or gravelly soils on low hills and slopes, sometimes on dry ridges along the rivers, make the favourable conditions for its development, but when the percentage of the soil moisture increases it passes over to *L. Gmelini*—Sociation; on the contrary, when that of sand increases it gives way to *P. sylvestris*—Association. This *Pinus* is sometimes distinguished from common *P. sylvestris* and called *P. s.* var. *jakutensis* SUKACZ. or *P. Takahasii* NAKAI. A characteristic feature of the Sociation is the absence of *Sphagnum* carpet in spite of its location in the northern site.

c) *Larix Gmelini—Pinus pumila*—Sociation (cf Fig. 79). This Sociation is situated at the highest position of these Sociations cited above and shows its characteristic feature in a transitional phenomenon from the subalpine to alpine zone. It occurs mostly along the lower margin of the tree limit, however the dominant tree, *L. Gmelini*, does not appear so much dwarfed and *P. pumila* also holds a half erect posture, sometimes 2–2.5 m high. It occupies mainly the upper parts, especially north-faced slopes of more than 1000 m in height, of Mt. Gashyosan (臥松山) near Aerhshan (阿爾山) and the writer has found its location in the southern distributional limit. Besides *P. pumila*, in the woody undergrowth layer, there also grow *Potentilla davurica* NESTL., *Berberis sibirica* PALL., *Empetrum nigrum* var. *asiaticum* NAKAI, and *Juniperus sibirica*.

2) *Larix Gmelini—Betula platyphylla*—Consociation (Subassociation). In this Consociation, besides *L. Gmelini*, *B. platyphylla* may form a considerable constituent and occasionally developes as well as *L. Gmelini*; and somtimes the Consociation passes over to *B. platyphylla*—Consociation. But the trees, such as *Tilia amurensis* or *Betula davurica* are either absent or present as isolated individuals. There are extensive tracts of burned area especially on the south or southwestern slopes where this Consociation has been developed and usually accompanied by *Vaccinium Vitis-Idaea* and *V. uliginosum* in the dwarf shrub layer.

(iii) *Larix Principis-Rupprechtii*—Association. This occurs generally in the North China Region, but for the reckless cutting by the inhabitants its actual remains have been confined to a few places at present, such as Weicheng (圍場), Lulipingzu-Shan (六里坪子山), Wuling-Shan (霧靈山), Hsiao-wutai-Shan (小五台山), Wutai-Shan (五台山) and the western neighbouring mountains near Ningwufu (寧武). It comprises two Consociations, *Larix Principis-Rupprechtii*—and *Larix Principis-Rupprechtii—Betula platyphylla*—Consociations.

Fig. 78. Distant view of *Larix Gmelini*—Sociation in the Davuria Region with isolated individuals of *Betula platyphylla* (face P. 625).
(M. TAKAHASI)

Fig. 79. A part of *Larix Gmelini—Pinus pumila*—Sociation on Mt. Gashyo-san (臥松山) in the Great Khingan Mountains (face P. 626).
(M. TAKAHASI)

Fig. 80. *Larix Principis-Rupprechtii*—Sociation on the rocky open stands at high altitudes of Mt. Wuling-Shan (face P. 629).
(M. TAKAHASI)

Fig. 81. *Betula Ermanii*—Sociation near the timber line on the Manchoukuo side of Mt. Hakutosan (face P. 630).
(M. TAKAHASI)

1) *Larix Principis-Rupprechtii*—Consociation (Subassociation). This Consociation occurs at more than 1500 m in height and it may be subdivided into the following two Sociations:

a) *Larix Principis-Rupprechtii*—Sociation (cf Fig. 80). This Sociation occupies mainly the upper part of the Consociation (1900–2600 m) especially the open stands, such as the sites where the landslips had occurred, and the tops of ridges or rocky places near the timber line.

b) *Larix Principis-Rupprechtii—Picea Mastersii*—Sociation. This Sociation is most prevalent in the portion ranging from 1800 to 2200 m in height, growing in the moderately wetter and richer soils, and as richness and thickness of the soils increase, *P. Mastersii* becomes more prolific. Besides the normal type it is also seen at the lower portion accompanied by *Juniperus rigida*, such as near Ningwufu (寧武), *Picea Meyeri* REHD. & WILS. at the middle portion, and *Betula chinensis* MAX. at the upper portion respectively.

2) *Larix Principis-Rupprechtii—Betula platyphylla*—Consociation (Subassociation). This usually occurs comparatively at the lower parts (from 1500 to 1800 m) and sometimes accompanied by *Pinus tabulaeformis* CARR. as seen on Mts. Wutai-Shan.

(2) **Cold-temperate summer-green dwarf Forest Formation.**(1)—This Formation occupies the upper slopes of high mountains along the timber line. The range in altitude naturally varies with the latitude; in the regions under consideration, it is from 800 to 1200 m in the northern Great Khingan Mountains, from 1800 to 2100 m at Mt. Hakutosan and from 2400 to 2600 m in the North China Mountains. This Formation is constituted by comparatively fewer Associations.

(i) ***Betula Ermanii—Alnus mandshurica*—Association.** This occurs in the East Manchuria and Davuria Regions, especially on Mt. Hakutosan and comprises two Consociations, *Betula Ermanii*—and *B. Ermanii—Alnus mandshurica*—Consociations.

1) *Betula Ermanii*—Consociation (Subassociation). This Consociation is most prevalent along the lower margin of the tree limit, and sometimes it grows well as to the size of tall trees, rarely of dwarf. It forms rather closed canopy, but on the wind-swept site it is typically open and stunted. It may be subdivided into the following three Sociations:

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(1) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 1135–1136, 1296–1299.

a) *Betula Ermanii*—Sociation (cf Fig. 81). It is usually found near the timber line of the East Manchuria Region, such as on the Manchoukuo side of Mt. Hakutosan as well as on Mt. Kwanbo in Korea, or rocky hills in the northwestern parts of the Davuria Region. It appears to be confined relatively to dry soils, and sometimes accompanied by its var. *incisa* KOIDZ. or *Larix Gmelini* in the Davuria Region.

b) *Betula Ermanii*—*Larix olgensis*—Sociation. This Sociation is used to occur in the transitional parts extending from *B. Ermanii*—Association down to *L. olgensis*—Association and it is mainly observed on Mt. Hakutosan.

c) *Betula Ermanii*—*Picea jesoensis*—*Abies nephrolepis*—Sociation. It is found in the transitional zone extending from *B. Ermanii*—Association down to *P. jesoensis*—*A. nephrolepis*—Consociation. And this Sociation also occurs on Mt. Hakutosan near the timber line.

2) *Betula Ermanii*—*Alnus mandshurica*—Consociation (Subassociation). This Consociation is situated at the locality similar to 1)—Consociation and usually occurs at the dryer and thinner sandy or gravelly soils, sometimes being accompanied by *Boschniakia rossica* HULT., a kind of parasitic plants, as the ground flora.

(ii) *Betula chinensis*—Association. This Association is most prevalent in the North China Region and usually occupies upper slopes of the mountains, but sometimes grows at considerably lower parts, attaining the size of tall trees, if light factor is favourable. In high altitudes, under the rigorous climate the trees are grown poorly, shorter in height and diameter, and not closed.

(F) Arctic or Alpine Vegetation Formation-group (Panformation).[1, 2, 3]

(Arctic or Alpine Scrub, Arctic or Alpine Grassland, Tundra, Heath, Hochmoor, and Summer-snow Waste Formations).

The climatic conditions of the arctic and alpine regions, especially in regard to their low temperature, strong winds and short growing seasons, are cited together, while the conditions dealing with other factors are treated separately. The climatic conditions of the alpine region are largely consequent on the reduced atmospheric pressure. For instance owing to the

(1) SCHRÖTER, C.: Das Pflanzenleben der Alpen. Ed. 2, (1926).
(2) TAKEDA, H.: Alpine flowers of Japan. (1938).
(3) TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 1808–1812.
——: Some ecological problems about the plants in high altitudes (Japanese). Bot. and Zool., 5 (1937) 286–300.

tenuity of the air, the absorption of the sun rays is reduced, the direct lighting and heating effects are more intense, and the difference of temperature between in the sunlight and the shade is greater than that of in the lowlands.

The alpine soil, especially in the East Manchuria and Davuria Regions, is usually very wet owing to the condensation of the moisture in the air. In this comparison it would not be necessary to emphasize the difference of the relative humidity between the air in the alpine zone and that of in the lowlands,(1) though the former is liable to somewhat quicker variation of humidity. It is very noticeable that the local difference of precipitation in the zones of Northern East-Asia varies so greatly, being lowest (about 500 mm) on Mt. Holan-Shan (賀蘭山) and highest (about 2500 mm) on the mountains near coastal regions, such as Mt. Hakutosan.

At certain times the intense heating of the alpine soil, especially in such semi-arid locality as the North China Region, causes a great evaporation and occasionally becomes so dry. It is also very interesting to find that in the alpine region the blue and ultraviolet rays are stronger than those at low altitudes, as has been indicated in the section of "Light".

Notwithstanding these conspicuous differences of the two regions, the xerophytic character common to the phanerogamic vegetations has usually attributed to the incapacity of the root-system to absorb water in the low temperature. Since the tissues most susceptible to injury by rapid changes of temperature and strong wind are the active-growing organs and the zone with the comparatively constant temperature is near the surface of the soil,(2) the plants are mostly of dwarf nature,(3) and bryophytes and lichens contribute greatly to make Arctic or Alpine Vegetation Formation-group. In general the meristems of the sexual organs seem to be more resistant to cold than those of vegetative organs, but many of these plants depend largely on vegetative methods of reproduction. Flowering and fruiting in these regions must

(1) As a rule, it is cited that the more ascending the mountain, the greater the condensation of water-vapour and its precitation in rain in consequence.

(2) During heating some of the energy is used for evaporation, while some heat-energy will be liberated when condensation occurs during cooling. Besides, when the soil is wet it becomes hot or cold rather gradually, owing to the greater specific heat of the contained water. In the alpine zone the height of a plant seems controlled by the degrees of temperature, one finds even the same plant of a meter taller living in the different zone of temperature, for the lower the height the more favourable for the growth.

(3) In general, besides these causes, the dwarfed trees have their origin in the dry soil (often being stony), but sometimes in the wet swampy soil with a low oxygen content, with the resulting sour soil.

be accomplished quickly or the cold will ruin all. So the acceleration of the reproductive phase is one of the characteristic features of flowering plants in the regions.

(1) **Arctic or Alpine Scrub Formation.**—This Formation comprises two Subformations, Arctic or Alpine summer-green Scrub and Arctic or Alpine needle-leaved Scrub Subformations.

In comparing the vegetation of Mts. Wutai-Shan with that of Mt. Hakuto-san, the absence or rarity of Arctic or Alpine Scrub and Heath Formations is especially noticeable. Most of the former alpine soils have higher pH value than neutral and this fact plays for eliminating these two Formations, although one must conclude that the scarcity of the precipitation is the most influencial factor for the delimitation.

(a) **Arctic or Alpine summer-green Scrub Subformation.** This Subformation is more or less resembling Cold-temperate summer-green dwarf Forest Formation, but rather stunted and open, occasionally seen isolated individuals. The trees would not be able to grow up to the size of tall trees on its summit, even should they be favoured in their growing conditions. This Subformation comprises the two Associations, *Betula fruticosa* – and *Astragalus* sp.—Associations.

(i) ***Betula fruticosa***—Association. This Association occurs in the Davuria Region and partly in the North China Region, comprising the following two Consociations:

1) *Betula fruticosa*—Consociation (Subassociation). This is usually confined to relatively dryer sites and sometimes mixed with *Alnus hirsuta* TURCZ. or *Corylus mandshurica*, rarely with *Spiraea salicifolia* L., but generally with *Vaccinium Vitis-Idaea* L., *Empetrum nigrum* L. and *Juniperus davurica* PALL. in the dwarf woody shrub layer. In the North China Region it is occassionally accompanied by dwarf *Salix*, such as *S. wallichiana* ANDERS.

2) *Betula fruticosa* (or subsp. *Ruprechtiana* KITAG.)—*Salix brachypoda*—Consociation (Subassociation). This is usually situated near the swampy depressions or along the streams, sometimes accompanied by *Alnus sibirica* FISH. et TURCZ., *Salix viminalis* L., *S. Capraea* L. and *S. repens* L.

(ii) ***Astragalus*** sp.—Association. Near the summit of the Peitai (the highest peak of Mts. Wutai-Shan) there are some bed rocks exposed to the action of light, wind and cold. The characteristic crevice community, however scaled small, is *Astragalus* sp.—Association. · This community is also found on Mts. Hsiao-wutai-Shan.

(b) Arctic or Alpine needle-leaved Scrub Subformation. In spite of occurring in many separate ranges, the Subformation generally holds a high degree of unity. Its typical Association is represented by *Pinus pumila*—Association growing practically through the northern alpine zone, except volcanic high mountains erupted in comparatively recent years such as Mt. Hakutosan. This mountain, lying between Manchoukuo and Korea, is the main peak of the same named volcanic chain. From the geological point of view[1] the mountain is a composite volcano of tholoide, built up of various alkaline rocks of trachytic type that erupted at the end of the Tertiary. After the formation of the caldera lake Tenchi (about 4 km in longer diameter), basic lava flowed out in the vicinity during the Quarternary Period, burying the mountain on its flank by repeated accumulations of the lava flows. But recently, perhaps a thousand or so years ago, severe explosions must have occurred after a long inactive period. This catastrophe began with a strong eruption accompanying immence eruptive substances of comparatively low temperature and buried the large areas of vegetations almost all of the upper slopes on Korean side by a thick accumulation of pumice or volcanic ashes of more than 10 m in thickness. So at the time it might be thought that greater part of large trunks remained yet under half buried condition, but after a short interval another severe eruption occurred with eruptive substances of high temperature. By the latter incident not only the rest half of buried trunks, but also led other vegetations of far wider areas to have caught fire and an actual new land-surface was formed for repopulation. These progresses of the catastrophe in the past are witnessed by the half burned buried trunks (1–10 m long) which remained frozen in the pumice layer. It was a good fortune that we could find these buried trunks almost as fresh as present ones preserved in this permanent ice and to be able to identify them which mainly consisting of the same as the present species, *Larix*, *Picea*, *Betula*, etc.[2,3] So if there were further exclusive excavations undertaken at the altitude from 2000 to 2200 m on the Korean side, frozen trunks of *P. pumila* might have been also found. To endorse this view, one may say that the present growing

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(1) KANO, T.: Glacial topography of the mountains of northeastern Korea. Geogr. Rev. Japan, **13** (1937) 1124–1143.

(2) MURAYAMA, J.: Studies on the carbonized trunks unearthed at the northwestern foot of Mt. Changpai-Shan. In Preliminary report of the synthetic investigation on Mt. Changpai-Shan. Rep. Changpai-Shan Exped. (Japanese). Chi-lin, S. M. R., (1940) 274–278.

(3) KOYAMA, N.: Die Holzarten des Waldes in fruheren Zeiten vor der Eruption in der Gegend vom Vulkan Hakutō. Bot. Mag. (Tokyo), **57** (1943) 258–273.

place of this *Pinus* has been on Mt. Minami-hotaisan (南胞胎山), lying only about 35 km from the caldera wall in the southward direction, and there was another place discovered recently on one of peaks belonging to the same volcanic chain lying westward in about the same distance. At any rate one thing is certain that this Association is lacking in the caldera wall and its immediate surrounding areas. On the other hand, this Association is found at the peaks of many mountains in the Davuria Region above the timber line, and of these mountains Mt. Gashyosan, as already illustrated, is in the southest location. The upper part of the Association on this mountain shows an appearance of creeping form as seen in the ordinary case, while its lower part has an almost erect posture of about 2 m high and passes over to (b) (ii) c)—Sociation.

Another Association belonging to the Formation concerned is *Juniperus davurica*—Association which sometimes occurs with the above Association, but usually grows completely independent of it.

(2) **Arctic or Alpine Grassland Formation.**[1, 2, 3, 4, 5, 6, 7]—In the arctic regions this Formation rarely occurs but Tundra Formation is prevailing. In the alpine regions, on the contrary, the Formation is always recognized more or less. This is because of the bad drainage, being characteristic to the topography of the former regions, keeping many mesophytic grasses, irrespective of their cold tolerance, for their suitable habitat. In the northern ranges of the regions under consideration this Formation finds its best development between 500 and 900 m, though it becomes more luxuriant as in further downward of the northern parts. However, it is of less importance in the southern or southeastern parts, owing to the scarcity of high mountains, excepting Mt. Hakutosan (2743.5 m), Mt. Wuling-Shan (霧靈山) (2050 m), Mts. Hsiao-wutai-

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(1) NAKAI, T.: Florula of Mt. Paiktu-san. (1918).

(2) KAWASAKI, S.: Hakuto Volcanic Chain. Chosen Nat. Hist. Soc., 4 (1927) 19–20.

(3) MORI, T.: On the flora of Mt. Hakuto. Chosen Nat. Hist. Soc., 4 (1927) 25–38.

(4) KITAGAWA, M.: A preliminary report on the vegetation of Mt. Changpaishan (Paiktusan), East Manchuria. Rep. Inst. Sci. Res. Manch., 5 (1941) 117–180.

(5) TAKENOUCHI, M.: A glimps of the vegetation of Mt. Wulong-Shan (Wuling-Shan), Jehol (Japanese). Rev. For. Exper., Manch., 3 (1940) 66–75.

(6) ——: Notes of the forest ecology of Mt. Changpai-Shan, with vascular plants list (Japanese). Ibid. 5 (1942) 39–72.

(7) BANDAI, G.: Preliminary notes and biology of Changpai-Shan expedition in the year 1940, 1941 from Fu-sung and An-tuo, East Manchoukuo (Japanese). Transac., Biolg. Soc, Manch., 5 (1942) 23–40.

Shan (小五台山) (2780 m), and Mts. Wutai-Shan (五台山) (3020 m). Among these mountains the most gorgeous appearance of this Formation is presented by a large area on the gentle slopes of Mts. Wutai-Shan. But on Mt. Hakutosan the true mat-herbage of the Formation is seen rather inferior to Heath Formation on the Manchoukuo side; both are poorly developed in the pumice area on the Korean side.

In general, the dominant or codominant species in the Formation are numerous and for the most part they constitute mixed communities of several species. In addition, the floral constitution somewhat varies according to different localities. This is partly due to the fact that, as a rule, this Formation is best developed in rather disturbed areas. Moreover, these communities indicate three well defined aspects, viz., early, middle, and late summer.

In limited areas of Alpine Grassland Formation, the vegetation is not only modified by the common factors of the lowlands, such as water supply, drainage, soil natures, etc., but also by special disturbing conditions (directly or indirectly) such as wind, snow and frost effects. Thus under the influences of these periodic actions, the vegetations are resulted more or less seral in stage. So basing on these habitat conditions, the Formation may be well classified into four localized types which are called "Habitype"(1) by the writer and described below respectively:—(a) Wet Situation Habitype, (b) Moist sheltered Situation Habitype, (c) Rock and Blocks Areas Habitype, and (d) Pumice Areas Habitype.

(a) **Wet Situation Habitype.** In the alpine zone of Mt. Hakutosan, owing to the porous nature of the ground, except the side of the "caldera lake" Tenchi and along its "barranco" Erhtopai-Ho (二道白河), lakes, pools and streams are of infrequent occurrence. In consequence the special vegetations which developed contiguous to wet situations are rarely met with, irrespective of much precipitation particularly in summer.

(i) On Mt. Hakutosan the following Sociations are found:

a) *Calamagrostis Langsdorffii—Ligularia intermedia*—Sociation. This Sociation makes usually a thick thicket on rich soils with prenty of water supply, as shown along streams in the upper parts of the subalpine forest and often stretches further upward beyond the tree limit, sometimes accompanied by the following species:

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(1) This subdivision is based mainly on habitat conditions, completely otherwise from that of Subformation order which is subdivided basing mainly on the life-forms, and usually used in the case of comparatively unstable communities.

Veratrum patulum LOES., *Aconitum macrorhynchum* TURCZ.,
Iris setosa PALL., *Cacalia hastata* subsp. *orientalis* KITAM.,
Geranium eriostemon FISCH., *Rumex Acetosa* L.,
Thalictrum aquilegifolium subsp. *asiaticum* KITAG., etc.

b) *Sanguisorba sitchensis* (var. *riishirensis*)—Sociation. This Sociation grows in sunny rich soils with ample humidity, as along rivulets in a valley and usually comprises the following species:

Ranunculus borealis TRAUTV., *Trollius japonicus* MIQ.,
Aconitum monanthum NAKAI, *Campanula glomerata* L.,
Ligularia Jamesii KOM., *Gymnadenia conopsea* R. BROWN.,
Sanguisorba affinis C. A. MEYER et REGEL & TILING, etc.

c) *Oxyria digyna—Saxifraga laciniata*—Sociation. This Sociation occurs either in half shaded rocky places with sufficient supply of humidity or along rivulets, and makes a mixed assemblage with no particular dominant. In most cases *Oxyria digyna* HILL and *Saxifraga laciniata* NAKAI & TAKEDA are comparatively noticeable, often accompanied by the following species:

Circaea caulescens var. *glabra* HARA, *Pleuropteropyrum ajanense* NAKAI,
Tofieldia nutans WILD., *Petasites saxatilis* KOM.,
Saxifraga punctata L., etc.

d) *Barbarea orthoceras—Juncus papillosus*—Sociation. This Sociation is usually found in rather lower lands, but on the Manchoukuo side it is, however being scarce, also witnessed in marshy places along rivulets into which hot springs are pouring. It sometimes comprises *Epilobium cephalostigma* HAUSSK., *Hypericum attenuatum* CHOISY, etc.

e) *Erophorum japonicum—Kobresia myosuroides*—Sociation. This Sociation occurs usually in damp or boggy places, for instance Shiginuma, where being more marshy; it is accompanied by *Equisetum limosum* L., *Sparganium simplex* HUDS., *Menyanthes trifoliata* L., etc. and *Drosera rotundifolia* L., *Oxycoccus microcarpa* TURCZ., etc. in somewhat boggy areas.

(ii) On Mts. Wutai-Shan and Mt. Wuling-Shan because of the shortage of precipitation and well drained topographic feature, wet situations are hardly found in the alpine zones.

(b) **Moist sheltered Situation Habitype.** The most luxuriant growth and the greatest number of phanerogams occur in the fairly moist and comparatively well developed soils of sheltered gentle slopes. This Habitype is a true climatic grassland and has a meadow-like appearance in the alpine zone. On Mts. Wutai-Shan, it covers a large part of the area above the timber line,

because the mountain at this altitude is rolling and not at all steep, having fairly thick soils with a suitable supply of moisture, where with few exceptions of scatterd individuals, as already cited, shrub thickets worthy to Alpine Scrub Formation are hardly found. Among these areas, of course, the depressions are characterized by a more luxuriant vegetation, and therefore by deeper deposits of humus, but the species are the same as those found on the other portions of the area.

(i) On Mt. Hakutosan, especially in the lower part of the alpine zone, this Habitype makes a colorful mat with scattered clumps of trees such as *Salix*, *Betula*, or *Larix* species, as already toutched, but not so largely scaled as that of Mts. Wutai-Shan.

a) *Trollius japonicus—Ranunculus borealis—Geranium dahuricum*—Sociation. This Sociation occurs on comparatively rich soils with sufficient supply of moisture, usually making up alpine mat-herbages of mixed assemblage with no particular dominant. Besides above mentioned species the followings are noticeable:

Artemisia Koidzumii NAKAI,
Bistorta vivipara S. F. GRAY,
Halenia corniculata CORN.,
Festuca ovina L.,
Geranium eriostemon FISCH.,
Parnassia palustris var. *multiseta* LEDEB.,
Roegneria Gmelini KITAG.,
Homopteryx Nakaiana KITAG.,
Dianthus superbus var. *speciosus* REICH., etc.

b) *Veratrum patulum—Ligularia intermedia—Thalictrum aquilegifolium* (subsp. *asiaticum*)—Sociation. This Sociation developes well on sunny declivities with rich moist soils, usually in the lower part of the alpine or upper part of the subalpine zone. It comprises the following species;

Ligularia Jamesii KOM.,
Prunella asiatica NAKAI,
Iris setosa PALL.,
Trifolium Lupinaster L.,
Phlomis koraiensis NAKAI,
Synurus deltoides NAKAI, etc.

c) *Iris Nertschinskia—Veratum Maackii—Gymnadenia conopsea*—Sociation. This Sociation occurs on wetter soils than preceding one and mostly in the upper part of the subalpine zone and sometimes lower part of the alpine, usually comprising the following species:

Hieracium coreanum NAKAI,
Ligularia intermedia NAKAI,
Lysimachia davurica LEDEB.,
Campanula glomerata L.,
Calamagrostis Langsdorffii TRIN.,
Chamaenerion angustifolium SCOP.,
Geranium eriostemon FISCH.,
L. jaluensis KOM.,
Luzula sudetica DC.,
Iris setosa PALL.,
Synurus deltoides NAKAI,
Lilium distichum NAKAI,
Senecio cannabifolius var. *davuricus* KITAG., ect.

(ii) On Mt. Wuling-Shan this Habitype mostly occurs as a kind of

so-called CLEMENTS' "disclimax"(1) which developes in disturbed areas after deforestation, instead of a climax i. e. a natural climatic grassland. To endorse this view, judging from its latitudinal location, even the summit (2050 m in altitude) might not have enough height to exceed the climatic tree limit.(2)

a) *Potentilla paradoxa*—*Dianthus superbus* (var. *speciosus*)—*Anemone narcissiflora* (subsp. *chinensis*)—Sociation. This Sociation developes well on comparatively rich and moderately moist soils fully exposed in the sunlight, usually making up a mixed assemblage with no particular dominant. Besides species above cited the followings are noticeable:

Lychnis cognata MAX.,
Paenia obovata MAX.,
Potentilla fruticosa L.,
Adenophora elata NANNF.,
Senecio nemorensis L.,
Convallria Keiskei MIQ.,
Aquilegia Yabeana KITAG.,
Thalictrum baicalense TURCZ.,
Vicia unijuga A. BRAUN,
Achillea sibirica LEDEB.,
Helictotrichon tentoehse KITAG.,
Gymnadenia conopsea R. BROWN,
Nepeta Stewartiana var. *robusta* NAKAI & KITAG., etc.

b) *Cacalia hastata* (subsp. *orientalis*)—*Astilbe chinensis*—*Synurus deltoides* (var. *Hondae*)—Sociation. This Sociaiton occurs in rich moist areas, either half shaded between open trees or fairly well exposed to the sun and often accompanied by the following species:

Lychnis cognata MAX.,
Sanguisorba officinalis var. *montana* FOCKE,
Chamaenerion angustifolium SCOP.,
Geranium eriostemon var. *megalanthum* NAKAI,
Cypripedium macranthum var. *ventricosum* REICH.,
Actaea acuminata WALL.,
Hypericum Ascyron L.,
Halenia corniculata CORN.,
Hieracium umbellatum L.,
Hemerocallis minor MILL.,
Delphinium grandiflorum var. *tigridium* KITAG., etc.

(iii) On Mts. Hsiao-wutai-Shan, according to the report of Y. TAKENAKA,(3) the following species are found in this Habitype, but our present informations are too limited to ecological classification:

Adenophora elata NANNF.,
Leontopodium linearifolium HAND.-MAZZ.,
Euphrasia tatarica FISCH.,
Bistorta vivipara var. *Roessleri* NAKAI,
Gymnadenia conopsea R. BROWN,
Saxifraga Limprichtii ENGL. & IRMSCH.,
Pleurogyne carianthiaca GRISEB.,
Scabiosa Fischeri DC.,
Silene tenuis var. *jenisser* FRANCH.,
Pedicularis Tatarinowii MAX.,
Dianthus superbus L.,
Aster alpinus L.,
Anemone narcissiflora var. *chinensis* KITAG., etc.

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(1) WEAVER, J. E. and F. E. CLEMENTS,: Plant ecology. Ed. 2, (1938) 86–88.
(2) It seems to be about 2400–2500 m in altitude.
(3) TAKENAKA, Y.: The vegetation of Mt. Hsiao-wutai-Shan (Japanese). Chosen Nat. Hist. Soc., 9 (1942) 144–156.

(iv) On Mts. Wutai-Shan, the altitude of the present upper limit of tree growth averages about 2500–2600 m on the northern sites and about 2400–2500 m on the southern sites. This Habitype, as already mentioned, covers a greater part of the area above the timber line—an area which is practically coextensive with the flat summit of the range and the slopes similar to it.

a) *Rheum undalutum—Veratrum nigrum*—Sociation. This Sociation occurs in comparatively rich and moderately moist soils on sunny declivities mostly on the upper subalpine zone, sometimes comprising the following species:

Heracleum morifolium WOLF, *Astragalus capillipes* FISCH. et BUNGE, *A. adsurgens* PALL., *Thermopsis lanceolata* R. BROWN, *Pedicularis striata* PALL., *Dracocephalum grandiflorum* L., *Leontopodium leontopodioides* BEAUV., *Silene repens* PATRIN, *Papaver* sp., *Stellera chamaejasme* L., *Hedysarum hedysaroides* var. *inundatum* HURUS., etc.

b) *Anemone Geum—Aster alpinus—Bistorta vivipara*—Sociation. This Sociation developes well on rich soil with ample humidity in the middle or lower alpine zone exposed in full sun, usually making up a mixed assemblage with no particular dominant. Besides species above mentioned the followings are noticeable:

Gentiana triflora PALL., *Thalictrum petaloideum* L., *Senecis flammeus* DC., *Trollius chinensis* BUNGE, *Rumex Acetosa* L., *Primula maximowiczii* REGEL, *Sanguisorba officinalis* var. *wutaiensis* HURUS., etc.

c) *Lagotis* sp.—*Anemone Geum*—Sociation. This Sociation occurs near and on the summit of high peaks such as Tontai or Peitai and comprises the following species:

Potentilla nivea L., *Gnapharium* sp., *Ranunculus pseudohirculus* SCHRENK, *Clematis macropetala* f. *brachypetala* HARA, *Bistorta vivipara* S. F. GRAY, *Pedicularis Oederi* var. *heteroglossa* PRAIN, *Aster alpinus* L., *Oxytropis wutaiensis* sp. nov., etc.

(c) **Rock and Blocks Areas Habitype.** On the Manchoukuo side of Mt. Hakutosan, the ground consists largely of rock outcrops or is covered with a mass of the blocks of various sizes. On the more elevated portions where blocks of very large size have been split off, no plants except lichens and mosses have as yet been able to gain a foothold. There are occassionally large areas where denudation has taken place by the action of landslide or snowslip and commonly resulted in the formation of screes. The shallow crevices are occupied by a rich moss and lichen mat, in which are imbedded

a few phanerogams, especially on the parts protected by snow in winter, though these areas show the possibility of transitions to Heath Formation. The lichen communities are certainly more variable than phanerogams with the chemical nature of the rocks.

The layer of broken materials protects the bed rock from further weathering; the blocks and fragments themselves are continually disintegrating under the influence of frost and lichens. Where the blocks are small and more disintegrated, a layer of fine materials has accumulated and more disintegrated, and a further stage is seen when the vegetation becomes more luxuriant both in number of species and of individuals. In general, the pioneers, which come in the alpine region of this kind, depend upon the amount of water and the condition of the rocks. In the mature areas the rock fragments have mostly broken down to form, with the humus deposit, an even layer of soil which is well covered by a growth of low herbaceous vegetation. But it does not perfectly correspond with the common idea of grassland, since the vegetation is very low and takes carpet-like appearance and mixed with extremely dwarfed shrubs which resembles quite closely to that of Heath Formation.

(i) On Mt. Hakutosan the following Sociations are found:

a) *Papaver radicatum*—Sociation. This Sociation is considerably seral in stage and occurs usually in small patches on dry gravelly areas or loose debris exposed in full sun. It is sometimes accompanied by the following species:

Minuartia macrocarpa OSTENF.,	*Arabis coronata* NAKAI,
Petasites saxatilis KOM.,	*Oxyria digyna* HILL,
Rhododendron Redowskiaum MAX.,	*Luzula sudetica* DC., etc.

b) *Luzula sudetica—Hierochloë alpina*—Sociation. This Sociation occurs in the similar areas to that of a)—Sociation and usually mixed with the following species:

Luzula Wahlenbergii RUPR.,	*Carex longerostrata* C. A. MEYER,
Carex atrata L.,	*Carex lenaeensis* KUKENT.,
Deschampsia caespitosa BEAUV.,	*Kobresia myosuroides* FIORI & PAOL., etc.

c) *Chrysanthemum Zawadzkii* (subsp. *aculilobum* var. *alpinum*)—Sociation. This Sociation is growing on sunny location in gravels or on rocks of different nature as well as volcanic scoriae, sometimes on well drained shallow soils. It comprises occassionally the following species:

Erigeron consanguineum KITAM.,	*Saussurea alpicola* KITAM.,
Senecio nemorensis L.,	*Bupleurum euphorbioides* NAKAI,
Gentiana algida PALL.,	*G. Jamesii* HEMS.,
Euphrasia tatarica FISCH.,	*Dianthus superbus* var. *speciosus* REICH., etc.

d) *Dryas octopetala*—Sociation. *D. octopetala* L. has a half-shrub nature and usually grows in dense colonies. This Sociation mainly occurs on stony places exposed in full sun, sometimes with medium moisture, but often in rather dry areas, comprising the following species common with Heath Formation:—*Rhododendron chrysanthum* PALL., *Phyllodoce caerulea* BABING., *Vaccinium uliginosum* L., *V. Vitis-Idaea* L., *Empetrum nigrum* var. *asiaticum* NAKAI, etc.

e) *Sedum elongatum*—*S. Fenzelii*—Sociation. This Sociation occurs between rocks or in crevices, either half shaded or fairly exposed to the sun with moderate supply of moisture, sometimes comprising the following species:

Sedum Aizoon L., *Minuartia macrocarpa* OSTENF., *Saxifraga laciniata* NAKAI & TAKEDA, *Tofieldia nutans* WILLD., *Lloydia serotina* REICH., *Phyllodoce caerulea* BABING., etc.

f) *Oxytropis Anertii*—*Silene repense*—*Aquilegia japonica*—Sociation. This Sociation usually occurs on thin soils on rocks or in crevices exposed in the sunlight with medium humidity and makes up a mixed assemblage with no particular dominant, but *Oxytropis Anertii* NAKAI, *Silene repense* PATRIN and *Aquilegia japonica* NAKAI & HARA are comparatively abundant, often accompanied by the following species:

Gentiana Jamesii HEMS., *Tilingia Tachiroei* KITAG., *Lloydia serotina* REICH., *Artemisia Koidzumii* NAKAI, *Geranium dahuricum* DC., *Dianthus morii* NAKAI, *Cerastium koreanum* NAKAI, *Astragalus uliginosus* L., *Pedicularis verticillata* L., etc.

(ii) On Mt. Wuling-Shan *Chamaerhodiola wulingensis*—*Thymus quinquecostatus*—Sociation is found. This Sociation usually occurs in sunny places between rocks or in crevices and often accompanied by the following species:

Sedum Aizoon var. *austro-manshuricum*, *Potentilla fruticosa* L., *Rubus saxatilis* L., *Triganatis amblyosepala* NAKAI & KITAG., *Viola biflora* L., *Saxifraga pekinensis* MAX., *Ligusticum jeholense* NAKAI & KITAG., *Tilingia filisecta* NAKAI & KITAG., *Melandrium apricum* ROHR., *Silene tenuis* var. *jenisser* FRANCH., *Dianthus chinensis* var. *longisquama* NAKAI & KITAG., etc.

(iii) On Mts. Hsiao-wutai-Shan, according to the report of Y. TAKENAKA, the following species are found in this Habitype, but from the ecological point of view our present knowledge about this mountain is too limited for further discussions:

Chrysanthemum sibiricum var. *latilobum* NAKAI,
Silene tenuis var. *jenisser* FRANCH.,
Geranium davuricum DC.,
Cerastium sinicum NAKAI,
Rubus saxatilis L., etc.
Sedum Aizoon L.,
Dianthus superbus L.,
Potentilla nivea L.,
Androsac hopeiensis NAKAI,

(iv) On Mts. Wutai-Shan this Habitype is rarely found on very restricted areas, such as near the summit of Peidai Peak.

Chamaerhodiola wulingensis—Chrysanthemum sibiricum (var. *latilobum*)—Sociation. This Sociation occurs on rocks or between crevices fully exposed in the sun and often accompanied by the following species:

Sedum Aizoon L.,
Astragalus saxicola ULB.,
Oxytropis wutaiensis sp. nov.,
Potentilla fruticosa L.,
Dianthus superbus L.,
Euphrasia tatarica FISCH.,
Leontopodium linearifolium HAND.-MAZZ.,
Dasiphora fruticosa var. *Veitchii* NAKAI,
Cerastium sinicum NAKAI,
Minuartia sp., etc.

(d) **Pumice Areas Habitype.** This is restricted to fewer volcanoes such as Mt. Hakutosan where pumice fields are covering a very large area on the Korean side, while it is absent from the greater part of the Manchoukuo side where basalt, tuff, obsidian, and trachyte are prevailing. The surface of the area moves slowly and has a characteristic appearance of sand-dunes owing to the southwesterly wind prevailing in spring and summer. So the area is too unstable to support any closed vegetation. Any vegetation present in pumice fields is confined to the leeward side of the rolling wave of pumice-stones. In this connection it is also interesting to note that *Potentilla fruticosa* L., which indicates the area being considerably dry nature, grows very luxuriantly on the Korean side of Mt. Hakutosan as well as on Mts. Wutai-Shan, but none is observed on the Manchoukuo side. On the Korean side, where the alpine zone merges into the subalpine, besides herbs and extremely dwarfed shrubs, there is a creeping growth of wind timber, consisting almost wholly of *Larix olgensis* A. HENRY.[1] Somewhat lower down and on less windy places the trees are upright, but have no branches on the windward side. In these places the following Sociations are found:

(1) The altitude of the present upper limit of tree growth averages about 1800 m on the Korean side, while 2100 m on the Manchoukuo side. The trees on the former especially form an open growth, with the individuals which usually are growing singly and having most fantastic shapes. The trees on the former are mostly *Larix olgensis* A. HENRY, while that on the latter are mainly *Betula Ermanii* CHAM., occassionally *L. olgensis*, *Picea jesoensis* CARR. or *Abies nephrolepis* MAX. These are important differences between the communities on the two sides.

a) *Chrysanthemum Zawadzkii* (subsp. *acutilobum* var. *alpinum*)—*Papaver radicatum*—Sociation. This Sociation may be thought of a mixed community of (c) (i) a)—, c)— and f)—Sociations and usually occurs on comparatively dry sunny places. It often comprises the following species:

Minuartia macrocarpa OSTENF.,	*Dianthus Morii* NAKAI,
Oxytropis Anertii NAKAI,	*Cerastium koreanum* NAKAI,
Viola biflora L.,	*Gentiana algida* PALL.,
G. Jamesii HEMS.,	*Saussurea alpicola* KITAM.,
Senecio nemorensis L.,	*Luzula sudetica* DC., etc.

b) *Dryas octopetala*—Sociation. This Sociation is almost the same as (c) (i) d)—Sociation except some induced members, such as *Potentilla fruticosa* L., and occurs on windy pumice fields.

c) *Sedum elongatum*—*S. Fenzellii*—Sociation. This Sociation is almost the same as (c) (i) e)—Sociation, and usually occurs at non-windy places. It developes rather inferior in growth and frequency than that of the latter case.

d) *Ptilagrostis mongholica*—Sociation. This Sociation is restricted on the Korean side and usually occurs in gravelly or sandy places (of pumice origin) where may be invaded later by other herbaceous plants. It is often accompanied by some of the following species:

Agrostis Trinii TURCŻ.,	*Deschampsia caespitosa* BEAUV.,
Hierochloë alpina ROEM. & SCHULT.,	*Trisetum spicatum* RICHT.,
Carex atrata L.,	*Luzula sudetica* DC., etc.

Some parts of the pumice area are kept wet throughout summer by the melting snow and ice under grounds. The permanent ice beneath (75 cm under the surface at the tree limit) prevents further absorption, therefore the water remains stagnant or flows very slowly below the surface. On such places the best development of the community is found, of course, the majorities of these growing species are of comparatively moisture-loving nature, owing partly to much precipitation in summer.

e) *Sanguisorba sitchensis* (var. *riishirensis*)—Sociation. This Sociation usually forms a dense mass of pure colony on sunny situations with sufficient supply of underground moisture or along rivulets, and often accompanied by *Sanguisorba affinis* MEY. et REGEL & TILING, *Campanula glomerata* L., *Hieracium umbellatum* L., etc. around the colony.

f) *Campanula glomerata*—*Hieracium umbellatum*—Sociation. This Sociation occurs on comparatively rich soils with ample humidity, usually making

up a mixed assemblage with no particular dominant. Besides species above cited the followings are noticeable:

Hieracium coreanum L., *Ligularia intermedia* NAKAI,
L. Jamesii KOM., *Parnasia palustris* var. *multiseta* LEDEB.,
Ranunculus borealis TRAUTV., *Sanguisorba affinis* MEY. et REGEL & TILING,
Gymnadenia conopsea R. BROWN, *Halenia corniculata* CORNAZ, etc.

g) *Aconitum monanthum—Allium sacculiferum*—Sociation. The Sociation developes well on sunny declivities with plenty of moisture near rivulets and sometimes comprises the following species:

Chamaenerion angustifolium SCOP., *Dianthus chinensis* L.,
Parnasia palustris var. *multiseta* LEDEB., *Solidago virgaurea* subsp. *Coreana* KITAG.,
Adenophora pereskiaefolia var. *curvidens* KITAG., etc.

(3) **Tundra Formation.** (4) **Heath Formation.** (5) **Hochmoor Formation.**

As has been indicated in the section of "Bog Soils and Tundra Soils", Tundra Formation stretches from the Pacific to the Atlantic Coasts, occupying a broad zone between the timber limit and Summer-snow Waste Formation near the region covered with perpetual snow about the north pole. In fact only the extreme northern parts of the regions concerned belong to the Formation, and it is usually thought that they are confined to the arctic regions. But should Tundra Formation comprise so-called "alpine tundra", its presence would be also recognized in the above timber limit on the high mountains. If the latter case to be allowed, this Formation would be very complicated with Heath and Hochmoor Formations. In the arctic regions, on the contrary, there is so-called "arctic heath" or "arctic hochmoor" of various types. One finds in these places, where the drainage is comparatively good owing mainly to gravelly soils, many species of lichens and mosses presented being so-called "arctic heath". These plants play an important rôle in this Formation as well as in the normal type of Heath Formation in the alpine zone. On the other hand, the areas, where the drainage is poor, are generally associated with pools, supporting a kind of moss-bog community which is usually called "arctic hochmoor". For the sake of avoiding these complications, it seems agreeable could Tundra Formation be represented largely by the former and both "arctic heath and hochmoor" to be comprised into Tundra Formation. As already indicated, from SCHIMPER's idea, dwarfed growth, a distinctly xerophilous character, predominance of mosses and lichens, and the incomplete covering of grounds are everywhere characteristic of the tundra. At any rate, the most characteristic trait of this Formation is that there is no closed cover-

ing of flowering plants, besides there are many species still present though their growth is extremely slow, as judging from their size and weight.

This Formation is generally thought as a vegetation composed of lichens and mosses growing on a soil which is only thawed to a certain depth during the short summer in arctic latitudes. Sometimes the portion close to the surface of the peat ridges in the tundra zone remains frozen even in summer, and the surface itself is occasionally almost bare of vegetation over great streches, suggesting the transitional area to Summer-snow Waste Formation. The woody plants of these ridges are mostly creeping over the ground but some exceptions rising a half meter above the ground.

There are, however, various kinds of "tundra". SCHIMPER[1, 2] has already distinguished "moss tundra" and "lichen tundra". He also recognizes *Cladonia*-tundra, *Platysma*-tundra (with *Cetraria,* etc.) and *Alectoria*-tundra. GATES[3] also attempted to classify some of the main types of the tundra in Russian Lapland, and said that a first division would be into "rock tundra" and "moor tundra", having further subdivisions respectively.

On the other hand, Heath Formation should be regarded to occur above the timber line of high mountains where exposed to extreme variation of temperature and humidity, and its distribution is probably connected with the amount and duration of snow covering in the winter and spring. In the Formation a thin covering of soil, through which drainage is extremly rapid, coupled with exposure to frequent strong winds, militates against the development of vascular plants. The vegetations over wide areas are represented mainly by the carpets of mosses and lichens consisted principally of species of *Sphagnum, Cetraria* and *Cladonia,* with stunted phanerogams which belong mainly to *Ericaceae* and *Rhododendron,* sometimes *Empetrum, Salix* or others[4]. A typical Heath Formation of such is found on Mt. Hakutosan, where the abundance of heath-forming plants is in striking contrast to the scarcity of

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(1) SCHIMPER, A. F. W.: Pflanzengeographie auf physiologischer Grundlage (1898) 720–725.

(2) —— and F. C. VON FABER,: Ibid., Zwei Bände (1935).

(3) GATES, R. R.: Notes on the tundra of Russian Lapland. Jour. Ecol. **16** (1928) 150–160.

(4) On Mt. Hakutosan following dwarf shrubs are the most abundant and striking species.: *Dryas octopetala* var. *asiatica* NAKAI, *Rhododendron chrysanthum* PALL., *R. Redowskiaum* MAX., *R. confertissimum* NAKAI, *Vaccinium uliginosum* L., *V. Vitis-Idaea* L., *Phyllodoce caerulea* BABING., *Salix meta-formosa* NAKAI, *S. rotundifolia* TRAUTV. and *Juniperus sibirica* BURGS.

these species on Mts. Wutai-Shan, this probably being due to much precipitation and the greater relative humidity of the air than those of the latter.

Hochmoor Formation occurs in the swampy areas of considerably cold places where are not necessarily to be confined in the above tree limit, it is largely consisted of *Sphagnum* bogs making a kind of peat hillocks. The hollows between these hillocks are more or less covered with water. They retain water like an enormous sponge, dying below and growing above, and they measure 3–20 m in diameter and about 1–3 m in height. The surface sometimes appears to be dirty white or grey in color derived from the lichens such as *Cladonia*, *Cetraria*, etc. One finds the development of the hillocks usually in excellent conditions particularly for the growth of the moist tufts of *Carex*, *Scirpus*, *Juncus*, etc.(1) Of course, these grasses are accompanied by numerous shrubs in the northern part of the Davuria Region where this Formation is prevailing considerably. Among these shrubs *Vaccinium uliginosum* L., *V. Vitis-Idaea* L., *Chamaedaphne calyculata* MOENCH, *Ledum palustre* var. *angustum* N. BUSCH. and *Oxycoccus microcarpus* TURCZ. et RUPR. are noticeable.

Hochmoor Formation is one of the most important communities which alternates with the forests of Boreal or Subalpine Forest Formation-group. So in the section of the peat there are found sometimes the remains of *Betula* and *Picea*. These remains might have been resulted from the destruction of the forest edge by the growth of *Sphagnum* bog, that is, should the soils go wetter, the forest would be easily suppressed by the better adapted Hochmoor Formation. On the contrary, the forest could stretch much further into the Formation, if the soils should be turning drier than the present condition.

On Mt. Hakutosan Hochmoor Formation, dominated by *Sphagnum*, scarcely occurs around the tarns such as Shiginuma where *Drosera rotundifolia* L., *Oxycoccus microcarpus* TURCZ. et RUPR., and *Salix myrtilloides* var. *manshurica* NAKAI, are found, but the common peat-growing species, *Andromeda Polifolia* var. *grandiflora* LODD., *Rubus Chamaemorus* L. and *Chamaedaphne calyculata* MOENCH are entirely absent.

On the other hand, on Mts. Wutai-Shan, in spite of the vegetable debris accumulated by various plants, the telluric water which has a neutral or

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(1) In the northern part of Davuria Region *Carex Augustinowiczii* MEINSH. et KORSH., *C. Meyeriana* KUNTH, *C. pallida* MEYER, *Erophorum vaginatum* L., *Calamagrostis Langsdorffii* TRINIUS, *Heleocharis intersita* ZINSER., *Scirpus Tabernaemontani* GMELIN, *Juncus bufonius* L., etc. are found.

somewhat alkaline reaction (pH 7–7.8), prevents the formation of humic acids, so acid liking mosses such as *Sphagnum* are scarcely found.

(6) **Summer-snow Waste** (Snow-patch and Show-lie Vegetation) **Formation.**

This Formation occurs under more rigorous conditions than Tundra or Heath Formation, either at higher latitudes or altitudes, where being exposed to continual heavy winds and even in the midsummer the remnants of snow are still visible in some of depressions. Moreover, in most places the snow does not melt until late in the summer and thus special factors conditioning the growth of vegetation are introduced. The plants occurring in such habitats are able to withstand a low temperature though some heat is able to penetrate the snow, especially if it is pressed into a more or less icy mass. But in many cases the grounds are mostly bare of vegetation, with an exception of scattered patches of dwarf shrubs or herbs on stony or rocky areas. Other plants which give a character to these places are mosses and lichens, but they do not play such an important rôle as in Tundra and Heath Formations forming large masses. Occasionally on the surface of the snow in this Formation the presence of some bryophytes is recognized which may depend upon the accumulation of fine silt from the dust deposited. Red snow (*Chlamydomonas nivalis*) is common at these areas. This alga extends deeply into the snow and is better developed in the hollows than on the little ridges between the depressions. In high latitudes this Formation is found along the arctic coasts and it is very similar to and sometimes contains the same species as that on the high mountains above the tree limit.

In these areas occasionally the stones have become mixed with mud, either from their own disintegration, or brought down from the upper places. In such places, under a damp and open climate, with the continued frost action (expansion of the wet soil in freezing), the stones are gradually pushed out centrifugally from certain centres,(1) so that the surface is occupied by the so-called "soil-polygons" or "structured soils" of various types, some of the

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(1) For the theories as to the probable mode in which they are formed the reader is referred to these papers:

TAKAHASI, M.: A preliminary study of the northern part of East-Asia from the viewpoint of ecology (Japanese). Geography, 8 (1940) 774–778.

HUXLEY, J. S. and N. E. ODELL,: Notes on surface markings in Spitsbergen. Geogr. Jour. **64** (1924) 207–229.

ELTON, C. S.: The nature and origin of soil-polygons in Spitsbergen. Quart. Jour. Geol. Soc. **83** (1927) 163–194.

polygons being "mud-polygons", while others are "stone-polygons". These areas remain almost entirely bare of plants, because of the continued action of the frost, realizing a kind of "wander waste".

The maritime districts, such as the Okhotsk Region, suffer from the frequent sea-fogs and low clouds, which reduce the sunshine, at the same time increasing the relative humidity of the air. Clear weather is decidedly uncommon in this region even in midsummer, and consequently the light and heat necessary for the riping of the seed of the later-flowering species are not available in these districts. In general the restriction of growth rate and high death rate of the plants in this Formation is chiefly controlled by carbohydrate shortage[(1)] which based on diminished amount of assimilation during their growing season, and not by the supply of salts, water or combined nitrogen, although the possibility of shortage of nitrogen is stressed as being a contributory cause.[(2)] There is no doubt these carbohydrate shortage is mainly depending directly or indirectly upon the rigorous climatic conditions in the region. As a matter of fact, the growing season is short, often lasting but two months, and frost or freezing may occur at any time even during this short season especially at night.

At any rate, the Formation is totally different from that found in a closed vegetation where the death rate of a species is controlled by the intensity of ecological competition.

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(1) WAGER, H. G.: Growth and survival of plants in the arctic. Jour. Ecol., **26** (1938) 390–410.

(2) The bird-manuring produces distinctive (usually grassy) communities even in the most barren parts of Spitsbergen. The effect of abundant supply of nitrogen on the plants is pointed out and special communities depending on this extra supply are described in the following papers:

SUMMERHAYES, V. S. and C. S. ELTON,: Contribution to the ecology of Spitzbergen and Bear Island. Jour. Ecol., **11** (1923) 214–286.

——: Further contribution to the ecology of Spitzbergen. Ibid., **16** (1928) 205–264.

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— The end —

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